WIMAX Based on Wavelet Transform and Phase Matrix in Multipath Fading Channel

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Abstract

In this paper a proposed technique is used to improve the performance of Multicarrier Code Division Multiple Access WIMAX based on Discrete Multiwavelet Transform Critically Sampling DWT and Phase Matrix (PM) under the Additive White Gaussian Noise AWGN channel flat fading and frequency selective fading channels. This model is used to reduce the effect of multipath fading. The proposed model depends on multiplying the transmitted signal by a generated Phase Matrix (PM) at the transmitter side, and the inverse of phase matrix at the receiver side. The results extracted by a computer simulation for a single user. Then it compared with WIMAX based Fast Fourier Transform FFT and Discrete Wavelet Transform DWT for both systems. As a result, it can be seen that the proposed system have high performance improvement over traditional WIMAX, were the BER is widely reduced under different channel characteristics.

Keywords: WIMAX, Channel Models, Phase Matrix PM, FFT, DWT.

الخلاصة

في هذا الورقة ، تركيب جديد مُقتَرَحُ ل(WIMAX) مستند على تحويل المويجة المتعدد المنقطع للعينة الحرجة (DWT) و مصفوفة الطور. إن هذا النظام WIMAX المُقتَرَح حسن الموصفات عند اختباره مع نماذجِ مختلفةِ للقنواتِ (AWGN، الخفوت المستوي والخفوت الإنتقائي). هذا النظام المقترح يعتمد على ضرب الإشارة الداخلة بمصفوفة الطور و الإشارة الخارجة بمعكوس مصفوفة الطور. وقد تم إثبات بأنّ َهذا النظام المقترح يملك فاعلية معدل أخطاء (BER) أفضل من الـ(WIMAX) التقليدي الذي يستخدم محول فورير السريع (FFT) و تحويل الموجة(DWT) مع مصفوفة الطور ونتيجة لذلك النظام المقترح حسن نتائجه لمختلف أنواع القنوات المستخدمة وبمختلف عواملها.

1. Introduction

Wireless communications using WIMAX offer tremendous opportunity to support high data rate and combat the inter-symbol interference (ISI) due to the multipath propagation effects inherently present in the wireless channel. The use of single carrier modulation scheme may prove to be unfruitful, since the channel induced inter-symbol interference can easily distort the data carried by a single carrier. Multi-carrier modulation (MCM) offers the advantage of spreading out a frequency selective fading over many symbols, which effectively randomizes burst errors caused by fading or impulse noise, so that instead of several adjacent symbols being completely destroyed many symbols are only slightly distorted. However, the quest for better solution in terms of modulation techniques that could accommodate high data rates, continued and an idea of combining MCM with code division multiple access (WIMAX) was born in 1993 [Shun el at-2009]. To fulfil these demands, a new scheme which combines wireless digital modulation and multiple accesses was proposed in the recent years, namely, OFDM-WIMAX (Orthogonal Frequency Division Multiplexing-Code Division Multiple Access). In generally, there are three types of hybrid schemes, e.g. MC/DS-WIMAX (Multi-Carrier Direct Sequence CDMA), WIMAX and OFCDM (Orthogonal Frequency Code Division Multiplexing). The WIMAX scheme spreads the original data steam using spreading code and then modulates different carriers with each chip, i.e. spreading the chips in frequency domain and is the technique of interest to reader [Yee-1993, Yu-2005]. The second type spreads the serial to parallel converted streams using a spreading code and then modulates different carrier with each data stream, i.e., spreading in time domain [Yu-2005, Kit-2002]. The input data stream is spread using the spreading sequence which could be a Walsh-Hadamard code or a PN sequence [Zhang-2004, You-L. C. and Shiao-L. T., 2012], and the resultant chips after spreading the symbols are modulated into different subcarriers using the IDWT operator [Fazel-2002, Vasily-1999]. The end few symbols are appended at the beginning of the frame to act as the cyclic prefix. The cyclic prefix maintains orthogonality between the subcarriers in a multipath channel [You-L. C. and Shiao-L. T., 2012, Koga-2003]. The receiver first removes the cyclic prefix and then performs a DWT operation of the received symbols and brings them back to the frequency domain[Yuan-2004]. Then dispreading and decoding of the chips in frequency domain are performed for the traditional WIMAX [Baig-2007, Keita-2007].

2. WIMAX Models

A weakness of DFT-based OFDM is the large spectral overlap between frequency responses of filters corresponding to different sub-channels. This can be lead to substantial leakage of power between sub-channels and consequently induce inter-channel interference. An efficient discrete wavelet multi-tone was proposed by Sandberg and Tzannes [Yuan- 2004] in order to improve sub-channel separation, in which perfect reconstruction filter banks are used as transceivers [Qinghua el at 2009]. When the analysis and synthesis banks of perfect reconstruction filter bank are interchanged, the new structure becomes a transmultiplexer. Wavelet analysis is simply the process of decomposing a signal into shifted and scaled versions of a particular wavelet. An important property of wavelet analysis is the perfect reconstruction, which is the process of rebuilding a decomposed signal into its original transmitted form without deterioration. The conventional DFT-WIMAX is of very low cost and complexity. Due to the convolution property of the DFT, the effect of the multipath channel is converted into a single complex channel coefficient in each subcarrier. Therefore simpler frequency combining methods can be used to replace usually computationally complex time domain equalization algorithms. Although the use of cyclic prefix (CP) in Guard interval is an easy method to mitigate ISI, it leads to spectral inefficiency as well as decrease of data throughput. This leads us to the introduction of other multi-carrier modulation techniques such as filtered Multitone (FMT) that do not need the use of the CP. Wavelet based DMT is a form of filtered multitone modulation [Sobia el at 2005] [Roberto el at 2009, Gupta A., Chandavarkar B. R.,2012]. Hybrid Multicarrier WIMAX techniques try to combine WIMAX and OFDM in order to reap the benefits of both techniques. A user is assigned an orthogonal Walsh Hadamard code (WHC), to separate each user's data from the other users and prevent interference. Since the PN code length N is equal to the number of sub-carriers N_c, each chip of WHC code modulates a sub-carrier, and thus provides frequency diversity by spreading data in frequency domain. The transmitted signal is formed by first taking the input data stream and subjecting it to BPSK modulation, then it is spread and filtered by the sub-band impulse response. The simulation model of the original WIMAX is shown in Fig.(1) and the new proposed model is shown in Fig.(2) for comparison. It can be seen from these graphs that a new four blocks is added at the transmitter and the other four at the receiver, namely; Phase Matrix (PM), DWT, Phase Matrix, and the IDWT blocks are added at the transmitter and DWT, Inverse Phase Matrix (IPM), IDWT, and the Inverse Phase Matrix at the receiver. The model in Fig.(2)worked well in the AWGN and flat fading channel, but its performance decreases in frequency selective fading channel due to multipath effect. This problem can be overcome by the new model for WIMAX based DWT shown in Fig (2). By comparing this model with Fig(1) it can be seen that there are three new blocks added to this model, namely DWT block, PM block, and the IDWT block at the transmitter and the other four blocks at the receiver in reverse form. The first two blocks (IDWT, PM) at the transmitter side and the other last two blocks (IPM, DWT) at the receiver side can be removed if the channel estimation and compensation are done in time domain [Kit-2002, Gupta A., Chandavarkar B. R.,2012], at this case the performance of this model is not affected.

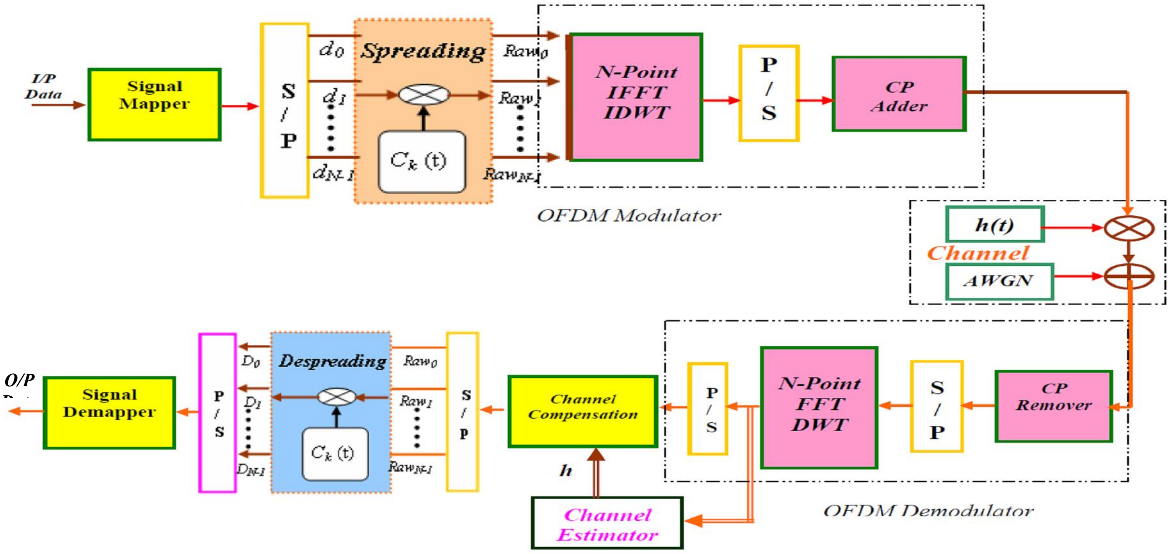


Fig. 1. Traditional Model of WIMAX based DWT and FFT

80 bit) that transmitted over the channel. A brief description of the simulation model shown in Fig.2 is described by the following steps:

1-The first four blocks they are stay as the same that given in Fig.1 with

a) A random bits are generated by a random source generator and every one bit are spreads at the third block with a user-specified spreading code [Fazel-2002]; (in this design every one bit are copied 32 times [Vasily-1999], which is equal to the Walsh-Hadamard code that used here (32 bits) and the output is the result of the Exclusive-OR of Walsh-Hadamard and the input bit. The output is a vector of length (1*32)

b) A zero padding of length (32 bits) is added to this vector to yields an output of (1*64) bits.

c) A training signal is generated of length (1*32) bits and zeroes are added to it of length (1*32) and the total training vector will be of length (1*64).

For both of data and the training signal the zero padding are added at the middle of the vector, namely the zeros are added from 17:48 bits, this signal are

a) A random bits are generated by a random source generator and every one bit are spreads at the second block with a user-specified spreading code [Fazel-2002]; (in converted to time domain by IDWT first stage).

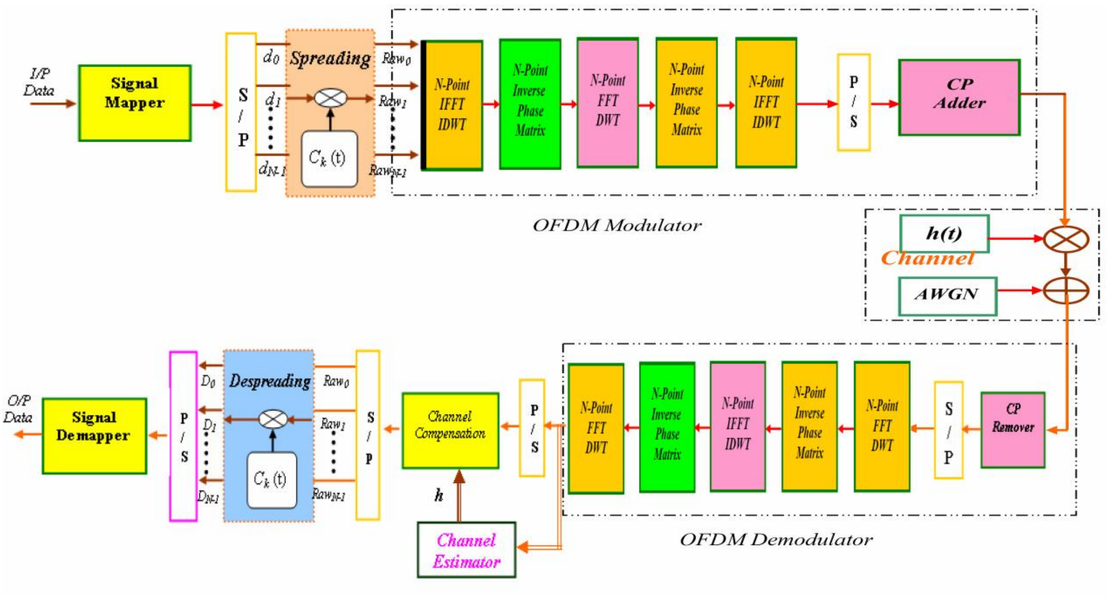


Fig. 2. A Proposed Model for WIMAX based DWT and FFT

2-The output of the IDWT for both data and training of length 64*1 bit for each one are multiplied by a phase Matrix of a size 64*64 to give an output signal of 64*1 as in Eq. (1).

$$x(n,i) = \sum_{v=0}^{M} x(n*M-(M-1)+v,i)\, e^{-j(2\pi/M).i.v} \qquad (1)$$

Where;

n: is the data bit number which is equal to the frame number.

i: is the frequency bin of the DWT or IDWT (from 1 to M)

M: the window size of DWT.

$x(n.i)$: is the output signal from the DWT

The Phase Matrix in Eq.(1) can be formulated in the following fashion;

$$P.M = \begin{bmatrix} e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*1} & e^{-j(2\pi/64)*2} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*63} \\ e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*2} & e^{-j(2\pi/64)*4} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*126} \\ e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*6} & e^{-j(2\pi/64)*9} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*189} \\ . & . & . & & . \\ . & . & . & & . \\ . & . & . & & . \\ . & . & . & & . \\ e^{-j(2\pi/64)*0} & e^{-j(2\pi/64)*63} & e^{-j(2\pi/64)*126} & \ldots\ldots\ldots\ldots & e^{-j(2\pi/64)*3969} \end{bmatrix} \qquad (2)$$

3-The output signal is processed at a NEW BLOCK (DWT Block) which does also not exist at the transmitter of the original WIMAX (fig. (1)) to yields a 64*1 output data.

4- Now the Data are multiplied again by the same phase Matrix of a size 64*64 to give an output of 64*1**.**

5- Then the data are multiplied an IDWT to convert it to time domain signal. Note that the last four steps are applied for both data and training signal which are in the same length in this simulation model.

6-The data and a pilot signal are now being converted to a frame structure; the total frame will be of length 1*180 bit which serially transmitted over the channel. In this simulation two types of statistical model of fading channels which are frequently used in the analysis and design of a communication systems, for more information reference [Roberto-2009, You-L. C. and Shiao-L. T., 2012] had analyzed these types of channels.

7- At the receiver the framing and a cyclic prefix are removed at the first block in the receiver.

All the remaining steps are done in the reverse fashion. The received signal is multiplied at the receiver by the Inverse of Phase Matrix (IPM) as in Eq. (3).

$$IDWT_{input} = IPM * DWT_{output} = (64*64)_{IPM} * (64*1)_{DWT} = 64*1 \qquad (3)$$

8. Remove the zeros that added at the transmitter for both data and training signal.

9. The training sequence will be used to estimate the channel frequency response as follows:

$$H(k) = \frac{\text{Re}\,ceived\ \ Training\ \ Sample(k)}{Transmitted\ \ Training\ \ Sample(k)} \qquad (4)$$

10. The channel frequency response will be used to compensate the channel effects on the data, and the estimated data can be found using the following equation:

$$Estmate.\,data = H^{-1}{}_{estimate}(k) * \text{Re}\,ceived\ \ data\,(k) \qquad (5)$$

11. Finally the signal is Exclusive Ored (XOR) with a Walsh-Hadamard of the user at the transmitter and the detection threshold decision are used to decide the value of signal.

It's important to say that the using of IDWT two times with DWT at the transmitter will give a good orthogonality for the signal which leads to improve the performance of this system [Yuan-2004].

An important factor that must be taken into consideration for this simulation is related with the power of the transmitted signal. Since the multiplication of signal and training vector by the phase matrix will cause an increase of the amplitude of the transmitted signal via the channel which cause the signal to be not affected by the channel and the simulation will be not correct, then the output signal that transmitted over the channel must be divided by (absolute mean value of signal), this will cause the mean value of the signal to be less than or equal to unity. In this simulation the transmitted signal is divided by twice of its mean value also the same thing for the training (i.e. transmitted signal/ (2*absolute mean (transmitted signal)), (transmitted training/ (2*absolute mean (transmitted training)). The signal here is divided by (2*2.5111) and the training is divided by (2*5). This cause the absolute mean value to be less than or equal to 0.5 which is widely accepted in the simulation. At the receiver the signal and training are multiplied by the same values that they divided on it in the transmitter.

4. Simulation Results

In this section, the combination of conventional WIMAX with the proposed WIMAX was studied. In this work the Walsh-Hadamard (code 32) has been used. A simulation of the two systems has been made using MATLAB 7.4. The BER performance of the two systems was studied over different channel models which are AWGN, and AWGN+ Multipath frequency selective fading channel, with a bit rate of 25 Mbps and 64 subcarriers are used in this simulation.

4.1 Performance of the Proposed System in AWGN Channel

In this section, the channel is modeled as an Additive White Gaussian Noise for wide range of SNR from 0dB to 40dB, from Fig. 3, it's found that the proposed system reach BER=10^{-4} at SNR=8 dB, while in the traditional WIMAX the BER=10^{-4} at SNR=23dB. This means a gain of 15 dB is obtained by the proposed model.

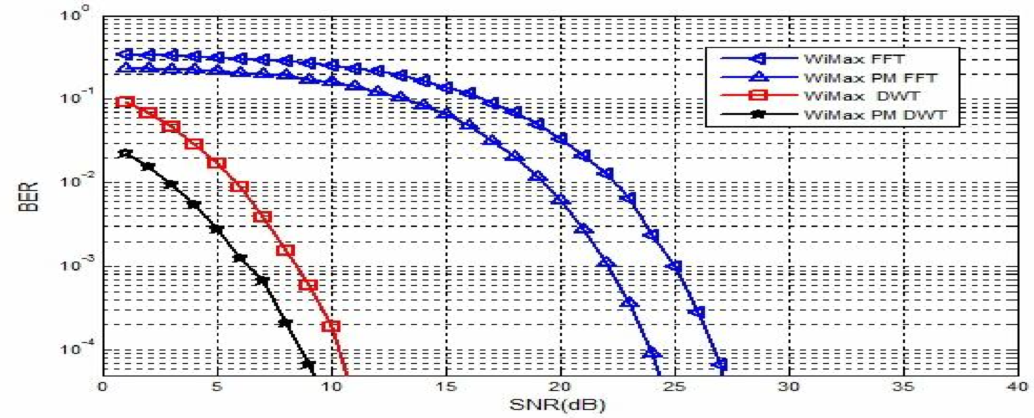


Fig. 3. Performance of the proposed and traditional WIMAX in AWGN channel

4.2 Performance of the Proposed WIMAX in Flat Fading Channel

The simulation results for both systems in flat fading channel are shown in fig.(4). Three values of the Doppler frequencies (*fd*) are considered in this simulation, these are *fd*=5Hz. From this figure it can be seen that the proposed WIMAX it still performs better than the traditional WIMAX using FFT and DWT in all values of the Doppler frequencies, where it approaches the BER=10^{-4} at SNR=31 dB and 36 dB when the Doppler frequencies are 5 Hz and 500 Hz. The BER increases as the Doppler frequency increases in both models. The traditional WIMAX is less sensitive to the variation of the Doppler frequency than the proposed one. For a BER=10^{-4}, the SNR=13 and 16.5 dB for the proposed model with 33, 34, and 34.5 dB for the traditional system, which means the gain is more than 18 dB was obtained from the proposed model at Doppler frequencies are 10, 50, and 500 Hz respectively.

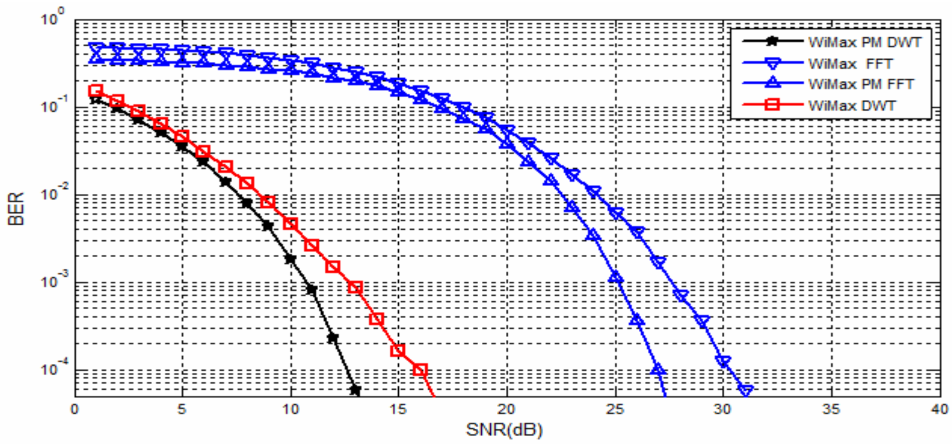


Fig. 4. Performance of the proposed and traditional WIMAX in Flat Fading channel at 10Hz

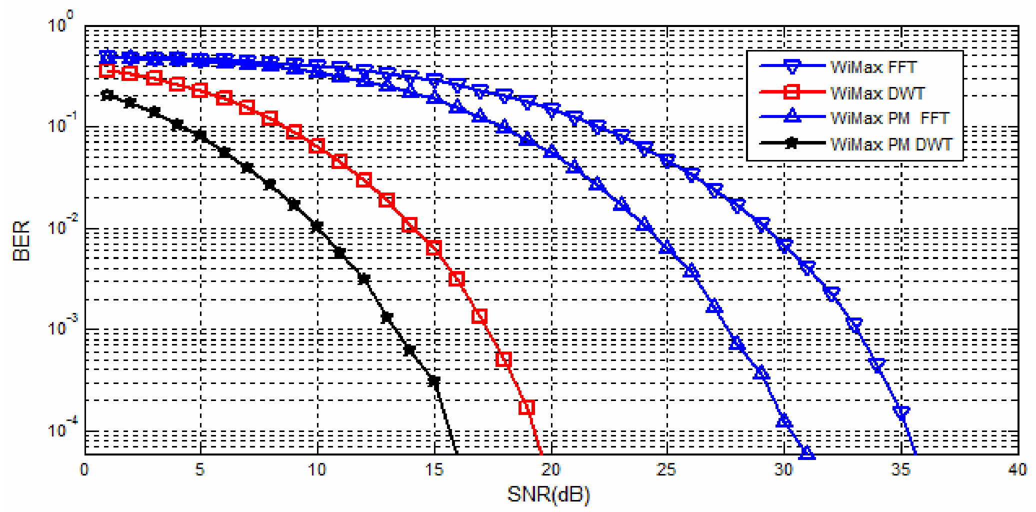


Fig. 5. Performance of the proposed and traditional WIMAX in Flat Fading channel at 50Hz

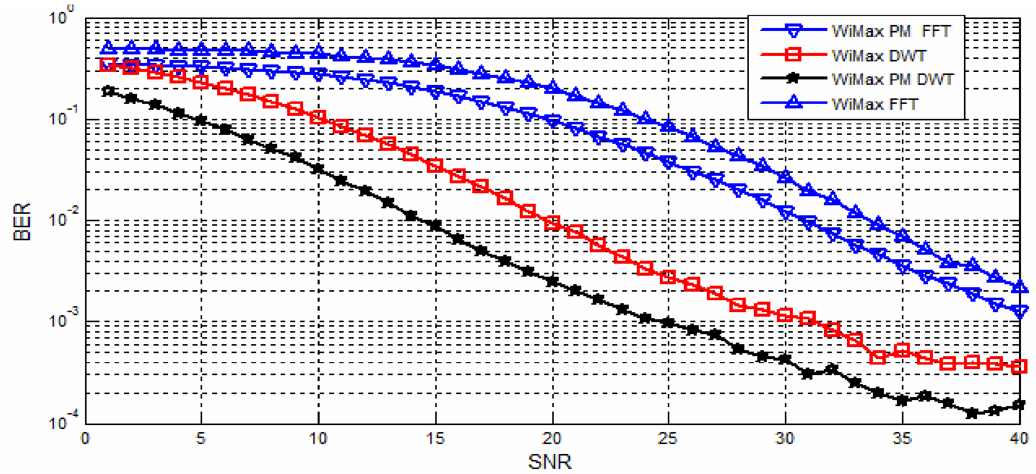


Fig. 6. Performance of the proposed and traditional WIMAX in Flat Fading channel at 500Hz

4.3 Performance of Proposed WIMAX in Multipath Fading Channel

Assume the two antennas at both the transmitter and receiver are sufficiently spaced, such that the channels between different transmit-receive antenna pairs are independent. Each channel is frequency-selective with respect to the overall system bandwidth, but each sub-band is assumed to be frequency non-selective with Rayleigh-distributed fade amplitudes. In this type of channel, the frequency components of the transmitted signal are affected by uncorrelated changes, where the parameters of the channel in this case corresponding to multipath, the two paths are chosen, the Line of Sight (LOS) and second path which is the reflected bath. Thus the right most columns for new tap 2, indicates the value of the total average relative power above, -4.4dB. The resulting model is given by Table 1. It has been validated using measurements in the 1GHz to 2GHz range, but is expected to be applicable at least in the range 450MHz to 5GHz. It is a wideband directional channel model capable of providing channel impulse responses in both spatial (azimuth and elevation) and temporal domains. The parameters of table 1 will be used in channel model at operating frequency 3.5GHz and different values of Doppler frequency

Table 1 Typical Urban (TU) Channel Model for UMTS WIMAX [3GPP 2004]

Tap Number	Relative Time (nsec)	Average Relative Power (dB)
1	0.0	-5.7
2	260.4	-7.6
3	520.8	-5.4
4	651.0	-11.5
5	781.2	-13.4
6	1171.8	-16.3
7	1302.0	-12.4
8	1562.4	-14.5
9	1822.8	-16.9
10	1953.0	-22.
11	2083.2	-20.1

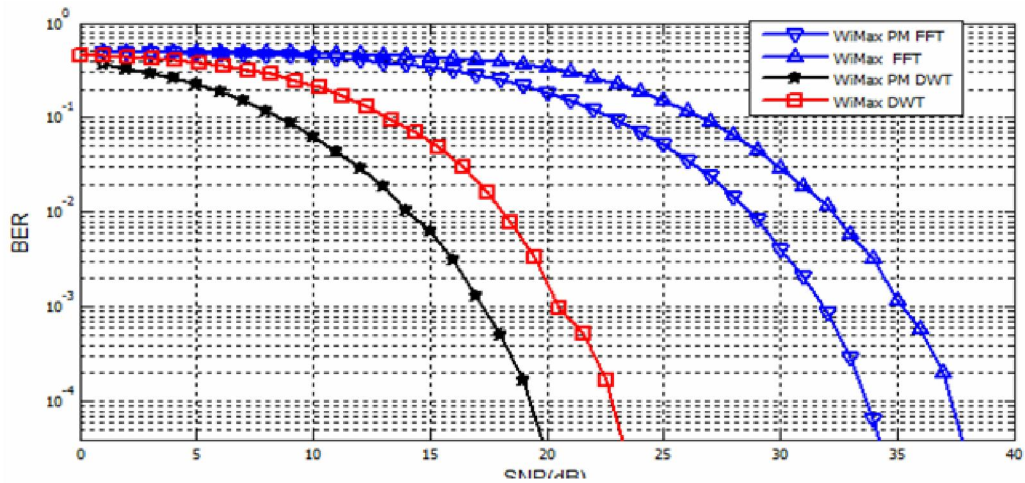
In selective fading channel many models have been taken consideration to compare the BER performance of the systems, the influence of the attenuation, delay and maximum Doppler shift of the echo is successfully discussed.

First, the Doppler shift parameter has been taken in interest, the model that have been used in the simulation set the Doppler shift to 5Hz, 50Hz and 500Hz. The path delay and the path gain are taken as shown in table 1.

It is seen that from Fig.(5) the proposed WIMAX is still performs better than traditional WIMAX. The SNR at a BER of 10^{-4} for the new one is about 18 dB, while it's a 38 dB for the original WIMAX, this means a gain of about 20 dB is obtained by the new way over the original system and this value is much active in the communications systems. Also a wide span improvement is appeared between these systems for all values of SNR.

Fig.(6) shows the performance of both systems in frequency selective channel when

the Doppler shift increased to 500 Hz, the SNR=25 dB and 39 dB for both proposed and traditional WIMAX at BER=10^{-4} respectively. The same gain approximately that obtained in Fig.(4) is obtained in this figure. The losses increased by about 2 dB for both systems due to Doppler Effect. Fig.(7) shows the performance under the same conditions in the last item except the Doppler frequency is assumed to be 500 Hz. The gain that obtained at 5 and 500 Hz is staying the same for the proposed model, and small increasing in BER for both systems.



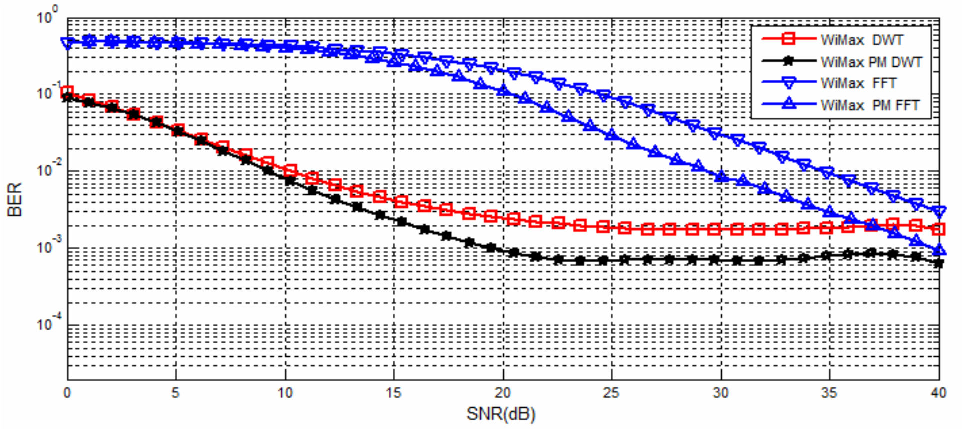


Fig. 8. Performance of the proposed and traditional WIMAX in frequency Multipath fading channel at maximum Doppler shift=50 Hz..

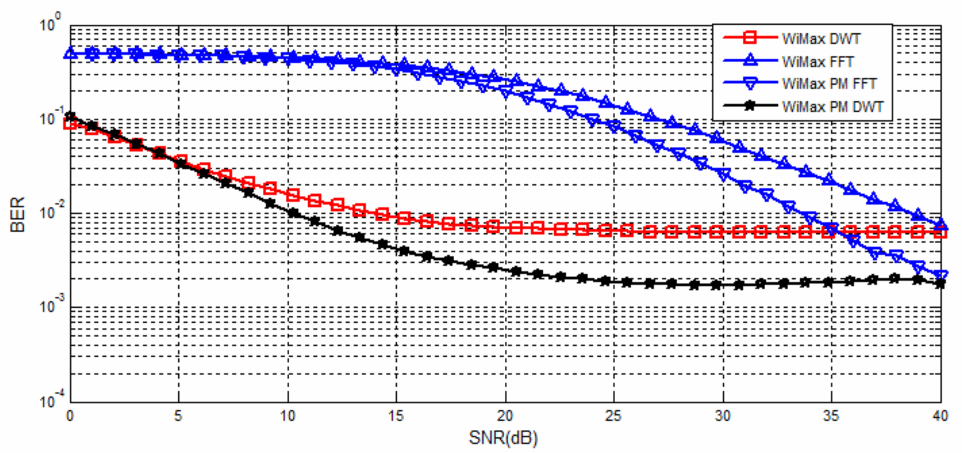


Fig. 9. Performance of the proposed and traditional WIMAX in frequency Multipath fading channel at maximum Doppler shift=500 Hz..

Based on the simplifications techniques outlined above, the other WIMAX deployment channel models were calculated and the simplified models of Generic Rural Area and Hilly Terrain (HT) are presented in tables 2 and 3 respectively. Another parameter can be checked is the path gain for the reflected path, the new value of the path gain shown table 2 at maximum Doppler shift of 5 Hz, The results are shown in Fig.8. Its clear form these results the effect of decreasing the paths gains for the reflected paths on the performance of both systems. The SNR required achieving a BER at 10^{-4} is decreased about 20 dB for both of them as the paths gains are changed.

Table 2 Generic Rural Area channel model for UMTS WIMAX [3GPP 2004]

Tap Number	Relative Time (nsec)	Average Relative Power (dB)
1	0	-5.2
2	42	-6.4
3	101	-8.4
4	129	-9.3
5	149	-10.0
6	245	-13.1
7	312	-15.3
8	410	-18.5
9	463	-20.4
10	528	-22.4

Table 3 Hilly Terrain (HT) Channel Model for UMTS WIMAX [3GPP 2004]

Tap Number	Relative Time (nsec)	Average Relative Power (dB)
1	0.0	-3.6
2	390.6	-6.5
3	520.8	-8.6
4	651.0	-9.8
5	781.3	-16.2
6	911.4	-14.5
7	14973.8	-17.6
8	16015.5	-22.7
9	16536.3	-24.1
10	16926.9	-23.9
11	17838.4	-24.6

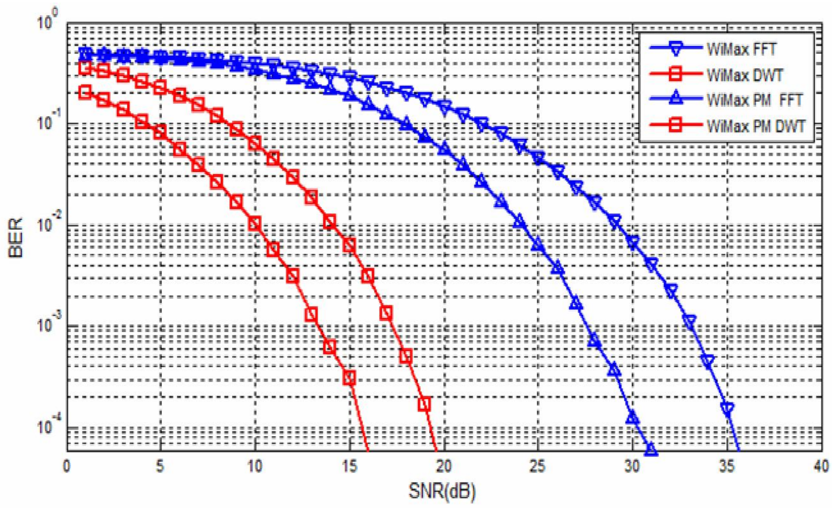


Fig. 10. Performance of the proposed and traditional WIMAX in frequency Multipath fading channel at maximum Doppler shift=10 Hz using parameters shown in table 2.

Finally, the path delay has been depicted, for the reflected path at a maximum Doppler shift 5 Hz. At this case the path delay and path gain taken as shown in table 3 are assumed. The results are shown in Fig.11. From this figure it’s obvious that a proposed WIMAX is still more active under this variations and the BER is decreased for both systems at a BER=10^{-4}. With a gain of 26 dB was obtained from the proposed model in comparing with the original WIMAX.

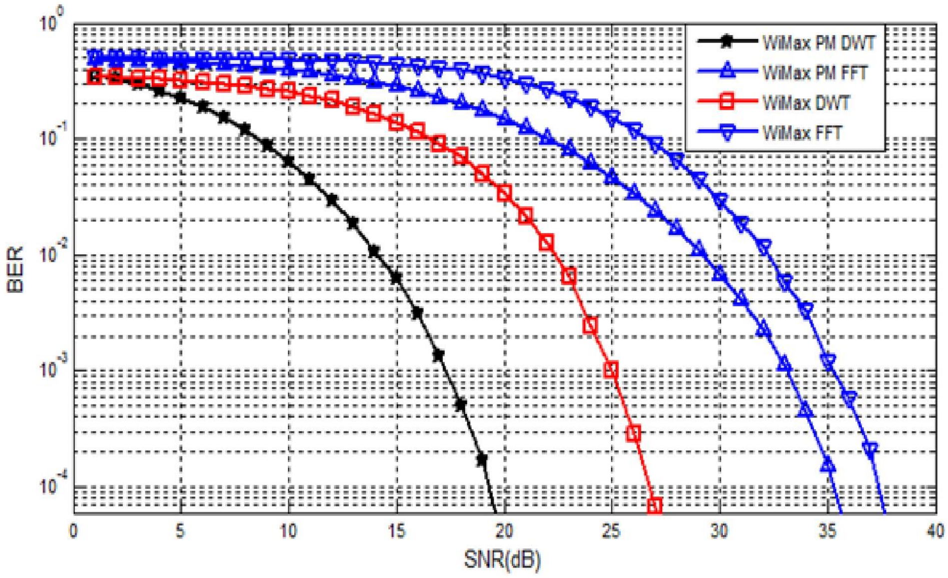


Fig. 11. Performance of the proposed and traditional WIMAX in frequency Multipath fading channel at maximum Doppler shift=10 Hz using parameters shown in table 3

5. Conclusion

The simulation of the proposed and traditional WIMAX systems has been investigated. It has been shown that the new algorithm is widely active to work under different channel characteristics. A gain of about 20 dB was obtained for frequency selective channel at different Doppler frequency shift. A gain of 19 dB appeared at the AWGN channel at BER=10^{-4} for the traditional WIMAX. The proposed WIMAX is less affected by changing the path gain and path delay used in simplified models of Generic Rural Area and Hilly Terrain (HT). As a result of using the phase Matrix, the BER performance was improved significantly, especially in the existence of multi-path fading channels on the average. An SNR gain of 6.5dB is gained to achieve an error of 10^{-4} in AWGN, flat fading channels respectively. While in multi-path frequency-selective channel SNR gain of 10.5dB is gained to achieve such BER.

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