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IMPLEMENTATION OF HYBRID MIMO OVER IEEE 802.16 USING REAL TIME SPEECH SIGNAL

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ABSTRACT

This paper presents the analysis of IEEE standard for wireless Metropolitan Area Networking i.e. WiMAX system with the implementation of Hybrid Antenna Diversity technique in its physical layer. Currently in the 4G standardized era, the goal of any developing technology is centered around just two features: Fastest performance and Highest accuracy. The development of IEEE 802.16 standard has bridged up the space between modern cellular telephony and recent networking technology aspects. As the WiMAX standard has been categorized as the 4G standard, obviously up to certain extent, it is fulfilling the above mentioned two features that the latest standard should possess but the advancements are still required under unfavorable conditions. The central idea of this paper is to wave off the limitation of this latest emerging standard by the implementation of hybrid antenna diversity scheme into it. The hybrid antenna diversity scheme is the well designed combination of Matrix A MIMO i.e. STBC system and Matrix B MIMO i.e. SM system. Matrix A MIMO is based on the Alamouti coding technique wherein the error performance can be improved by enhancing diversity gain whereas Matrix B MIMO is based on the VBLAST architecture that improves data rate by the application of multiplexing gain. In this paper, this concept has been realized by the MATLAB modeling of WiMAX structure with Hybrid MIMO technique.

Keywords: Wimax, Hybrid MIMO System, V-BLAST Structure, STBC, Data Rate, BER & SNR.

I. INTRODUCTION

The simple mobile phone can be considered as the best example of huge leap in the wireless technology. It has been evolved to provide just the simple calling functionality, but as a part of upgradation, it is becoming a multifunctional gadget which is playing a very significant role in retrieving email, surfing web and streaming video as well as audio files and much more. This proves the advancement in mobile technology from 1G analog version to 4G digital, fastest and accurate version.

As always, the demand is of highest speed and lowest error from the user and the service facilitators' end w.r.t. the existing standards, IEEE and ITU have proposed the 802.16 standard for wireless Metropolitan Area Networks known as WiMAX system. [13]

IEEE 802.16 is a long range, fixed and wireless, MAN technology which operates in the frequencies between 10 and 66GHz. The technology has a target

range of up to 31 miles and a target transmission rate exceeding 100Mbps. Inititally it was designed for NLOS application in form of IEEE 802.16 (a) standard but subsequently, two new standards have been evolved in form of IEEE 802.16 (d) i.e. fixed WiMAX and IEEE 802.16 (e) i.e. mobile WiMAX. Due to features of significantly high transmission rate and long range with enough accuracy, WiMAX has become the backbone for the existing Wi-Fi networks. As a whole, this invention has bridged up the gap between Wi-Fi standard and cellular GSM standard for providing extra high speed and mobility. [10]

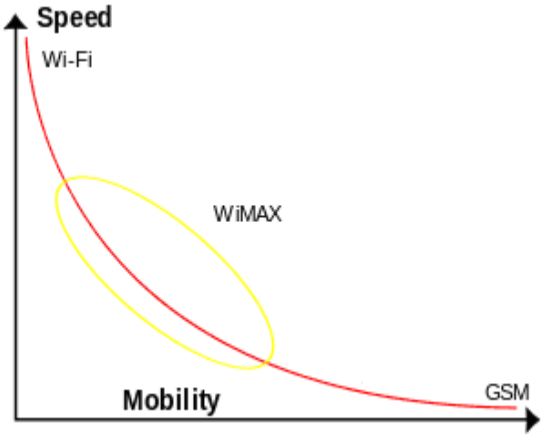

Fig-1: Relationship of WiMAX with WiFi and GSM

WiMAX has proven to be the strongest contender of 4G group because of following features:

1. Variable OFDM-FFT structure for LOS and NLOS application.
2. 20Mbps data rate and support of adaptive modulation as well as advance antenna system.
3. Efficient usage of bandwidth.
4. Robust due to ARQ protocols.
5. Secure due to implementation of AES and triple DES scheme.
6. IP oriented structure.

In spite of all these outstanding features, still the IEEE 802.16 WiMAX standard can be made superior among all with the adaptation of advance antenna techniques i.e. MIMO. This paper narrates the approach of Hybrid MIMO which is much more efficient than simple MIMO technique in the world of diversity. The following two consecutive sections deal with the basic architecture and advanced features of Hybrid MIMO and the numerical modeling and simulation of WiMAX standard with Hybrid MIMO structure along with the simulation results in speech form.

II. ANTENNA DIVERSITY & HYBRID MIMO TECHNIQUE

The traditional approach of wireless communication system analyzes fading as a culprit because the images arrive at the receiver at slightly different times and can thus interfere destructively. With SISO system, the signals are transmitted and received only once by single pair of antenna which will be having maximum fading effect. While with the implementation of diversity at transmitter or receiver side alone i.e. MISO or SIMO, the

error rate can be improved at certain extent but not fully because one can have multiple time transmission advantage whereas the other can have upper hand of averaging. Finally with the use of MIMO techniques, the best case with much lower error can be achieved for the betterment of system capacity. MIMO diversity technique uses multiple transmitter and multiple receiver antennas so that out of the multiple paths, atleast one accurate path can be obtained thereby reducing the error rate.

MIMO can be implemented in terms of two variants: space time coding (STC) scheme and spatial division multiplexing (SDM) scheme. The STC scheme increases link reliability and error performance, while the SDM scheme provides high speed data rate over wireless communication without additional transmit power or bandwidth. One interesting STC scheme is space time block coding (STBC) also known as Alamouti scheme. One of the most famous SDM scheme is the vertical Bell Laboratories layered space time (V-BLAST). [8]

(1) STBC Technique:

Alamouti introduced a very simple scheme of space-time block coding (STBC) allowing transmissions from two antennas with the same data rate as on a single antenna, but increasing the diversity at the receiver from one to two in a flat fading channel. This essentially requires at least two transmit antennas and at least one receive antenna. One of the choices of codes used is the Alamouti codes. [1] The purpose of this scheme is not to increase the system capacity but to improve the error rate performance of the system by transmitting coded information.

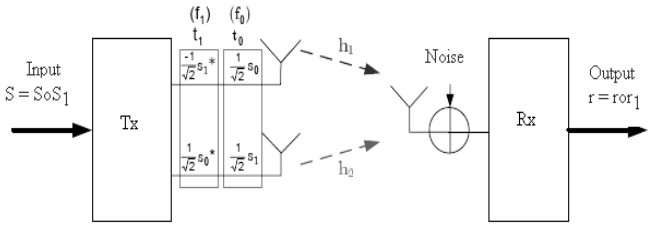

Fig-2: Alamouti Coding Scheme

As shown in figure-2, the data stream entering the Modulator is modulated into Symbols S1 and S2. These symbols are then processed by the Space-Time Encoder which then sends S1 followed by –S2* to Antenna 1 and S2 followed by S1* to Antenna 2. Here (*) denotes a complex conjugate of the symbol. Note that the two antennas at the transmitter will transmit 2 symbols in two time periods. [9]

(2) **VBLAST Technique:**

As contrary to the alamouti technique, in this case the data stream is bifurcated into substreams proportional to the no. of transmitting antennas and then individual antenna will transmit each independent substream which all are going to received and detected by multiple receivers. The idea behind the technique is to increase the data rate of the system dramatically by taking the advantage of multiplexing gain property of antenna diversity.

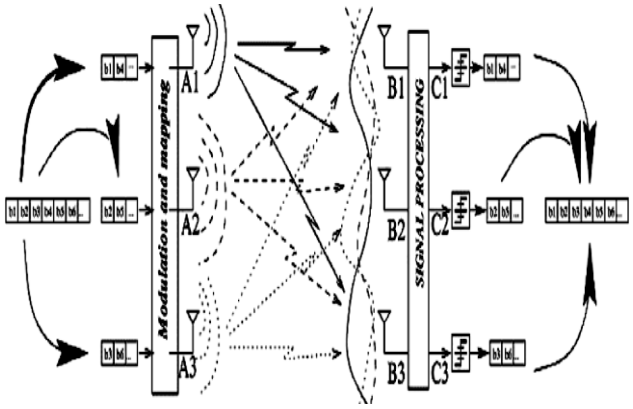

Fig-3: V-BLAST Architecture

In V-BLAST a single data stream is split into multiple sub-streams and multiple transmitter antennas are used to simultaneously launch the parallel sub streams as shown in figure 3. All the sub-streams are transmitted by using the same frequency band, so spectrum efficiency will improve drastically. Moreover the user's data is being sent in parallel over multiple antennas, the effective data rate is increased in roughly in proportion to the number of transmit antennas used. One thing that has to be made sure is number of receivers for this system must be equal to or greater than that of the transmitter. [2]

At the receiver, again the multiple antennas by the use of quality signal processing algorithms the individual substreams will be detected from the multiple copies of it at each side. In effect, the unavoidable multipath is exploited to provide a very useful spatial parallelism that is used to greatly improve data transmission rates. Thus, when using the V-BLAST technique, the more multipath, the better, just the opposite of conventional systems.

(3) Hybrid MIMO technique:

Most systems select either STC or SDM scheme. However, STC and SDM schemes are combined to obtain a hybrid system that attains both spatial multiplexing and diversity gains by reducing a little performance.

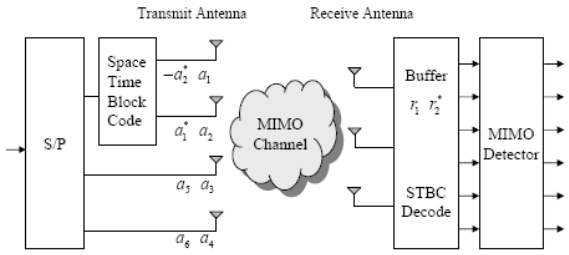

Figure 4 – Hybrid MIMO Scheme [8]

The following section elaborates the modeling of WiMAX standard with the inclusion of Hybrid MIMO technique to improve both error rate and data rate for achieving perfect 4G scenario.

III. MODELING & SIMULATION OF IEEE 802.16 STANDARD

3.1 Modeling with SISO (Traditional Approach)

Here in this section, the modeling of WiMAX has been carried out by considering the traditional approach where in single input single output (SISO) antenna system has been used. The following literature elaborates the block by block analysis of WiMAX-SISO model.

1. The system is initiated with speech transmission block. Input speech of 16000 samples would be captured and converted into the bits by means of "speech transmission" block and Scrambler.
2. Then after the data bits are encoded through the series combination of RS encoder and Convolution encoder as an outer and inner coder.
3. This data stream is modulated by means of M-ary Modulator which will be having order of modulation 8.
4. Now the output of modulator will pass through the normal SISO channel (here it is AWGN channel) and coming across the effect of traditional fading.
5. On the receiver side, the exact reverse process will take place and the signal would be recovered with plenty of errors due to wireless environment in form of recovered deteriorated speech.

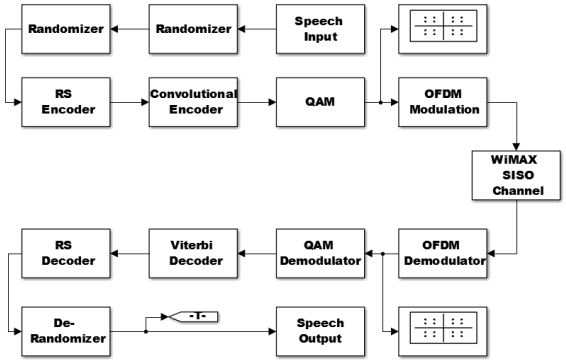

Fig-5: WiMAX – SISO Model

In the next three sub sections, the modeling has been carried out under the MIMO environment.

3.2 Modeling with MIMO-Alamouti

The modeling of WiMAX model with the inclusion of MIMO-Alamouti has been elaborated here. Up to step no. 3, the design is common. The remaining architecture has been explained here so as to anticipate the advantages of MIMO-Alamouti as discussed previously.

1. Through the combination of STBC encoder and OFDM transmitters, the signals coming from modulator will be undergone through the process of Alamouti coding in which two antennas are transmitting the same signals as shown in figure 6 so that on the receiver side any of the one branches can be better in terms of errors.

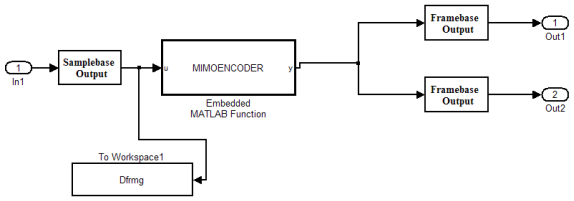

Fig-6: Almouti coded signal transmission

2. The speech will be passed through the MIMO-Alamouti channel as a next step and then passed towards the receiver.

3. The very first block of receiver system is OFDM receiver wherein FFT will be performed at the initial stage and then simultaneously cyclic prefix and training sequences will be eliminated.

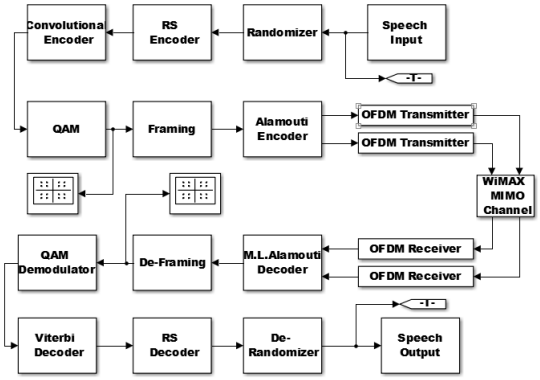

Fig-7: WiMAX – MIMO Alamouti Model

4. Then after the Alamouti decoding is performed by STBC decoder and the data will be fed to the next stages of demodulation, decoding and speech regeneration. The output speech is very smooth with lowest BER w.r.t. the previous SISO model output speech because of the advantage of improved diversity gain. [12]

3.3 Modeling with MIMO-VBLAST

As the above design anticipates the advantage of improved BER but the data rate is lower because both the antennas are transmitting the same signals, the model discussed in this section uses the modeling of WiMAX with MIMO-VBLAST to improve data rate.

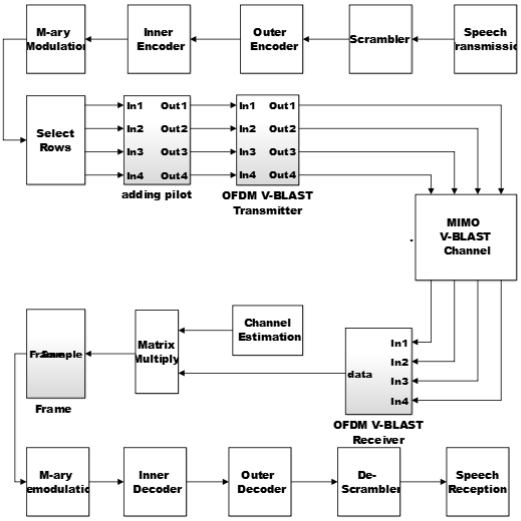

Fig-8: WiMAX-MIMO VBLAST Model

Again the steps 1 to 3 are common to the previous two designs. From 4th step, the VBLAST architecture has been implemented.

1. the transmission of different data sub streams through different antennas is carried out to form the VBLAST structure. Here prior to exact transmission, the complete modulated data stream of M-ary Modulator block will be divided into four sub streams as this system is having 4x4 designing of antennas. With help of multi port selector (Select Rows) utility block of MATLAB, this bifurcation of data stream into no. of sub streams proportional to no. of antennas is carried out as shown in figure 9. [4]

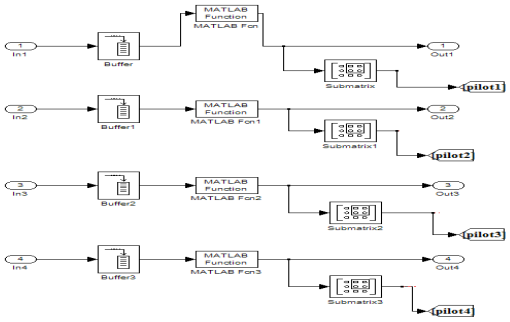

Fig-9: VBLAST coded Sig nal Transmission

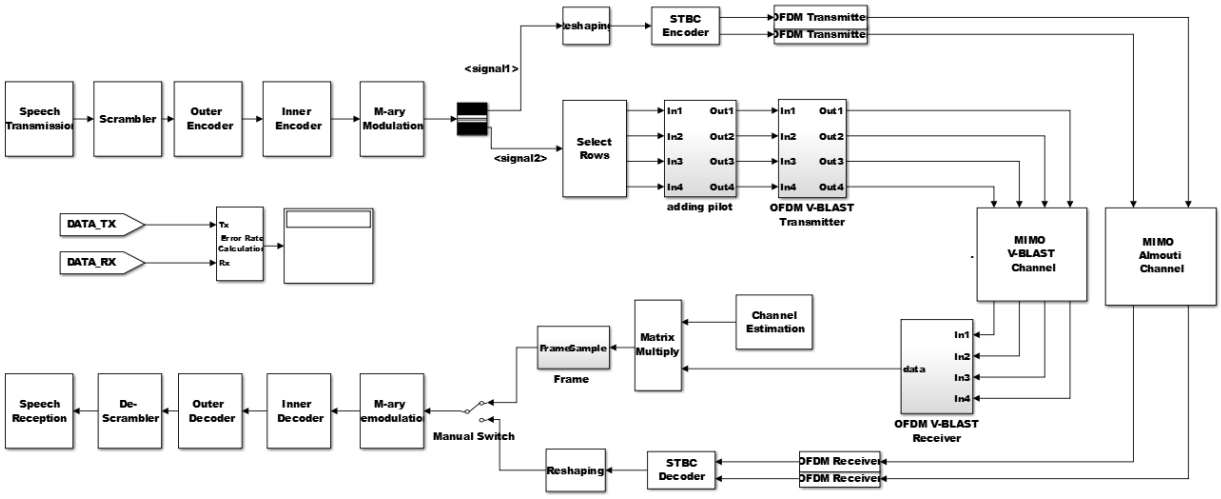

Fig-10: WiMAX – MIMO VBLAST Model

2. Further, as a next transmission step, the four data sub streams are combined with 64 pilot carriers by means of "adding pilot" MATLAB utility block and then undergone through the OFDM process.
3. Then the speech is passed through the MIMO-VBLAST channel and these four sub streams are given to four demultiplexers' assembly where the four BLAST pilots of size (64x1) will be separated from the data that are utilized to estimate the behavior of the channel. Subsequently the recovered BLAST pilots from the process of demultiplexing are used to estimate the behavior of channel. This task is carried out by LS channel estimation block which is doing ML detection. The process is getting completed by doing pseudo inverse of the output of LS estimation. Finally (4x4) matrix would be generated that gives the estimation of channel errors.
4. As a last step, speech is recovered by the processes of demodulation, decoding and reconstruction. Obviously data rate is increasing here because all the antennas are transmitting different signals simultaneously by anticipating increased multiplexing gain but with the compromise of error. One thing has to be noted down that though error is more w.r.t. MIMO-Alamouti, but very much lesser than that of SISO modeling.

As a whole, if both type of advantages are required to attain, the best design is Hybrid MIMO approach which is the key task of this research work that has been explained in the below section.

3.4 Modeling with Hybrid MIMO

As discussed above, this modeling of WiMAX standard is having the adaptive approach for the utilization of MIMO-Alamouti and MIMO-VBLAST. Under the clear atmospheric condition, where the chances of errors due to channel behavior are less, its better to increase the data rate without the concern of BER, so the better choice is VBLAST modeling whereas, in the reverse scenario, for the clumsy channel, to focus on BER, its better to go for MIMO-Alamouti.

Here from again in modeling, steps 1 to 3 are common. Then after both the approaches have been carried out adaptively through the design.

1. After modulation, the incoming signal will be divided into two parts which will follow two different mechanisms simultaneously to form the hybrid MIMO structure. One towards the MIMO-STBC mechanism wherein the alamouti coding is carried out so as to improve bit error rate (BER), while the other is towards MIMO-VBLAST mechanism wherein the spatial multiplexing is carried out so as to improve data rate.
2. The output data streams of the two routes will be passed through two channels i.e. MIMO-Alamouti channel and MIMO-VBLAST channel.
3. Now on the receiver side, the reverse process will be carried out and two kinds of speech output will be generated, according to the choosen diversity and either improved BER or improved data rate can be obtained as a part of advantage of Hybrid approach.

IV. SIMULATION RESULTS & DISCUSSION

As per the snap shot of WiMAX-SISO model shown in figure-5, by setting the value of SNR=24dB is simulated in MATLAB environment.

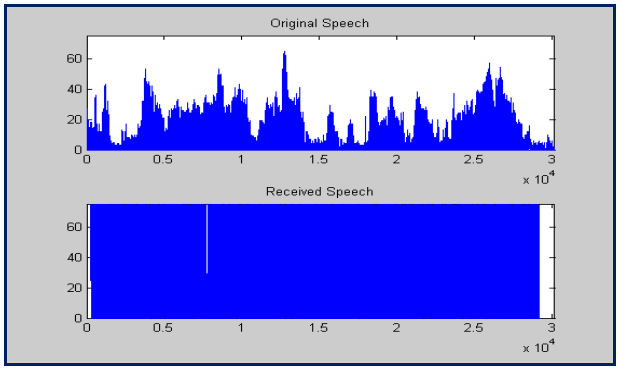

Fig-11: Output Speech SISO

The output speech is having major disturbances due to the traditional approach. Now with the simulation of WiMAX-MIMO Alamouti model and WiMAX-MIMO VBLAST model, the BER can be improved with a very significant approach which can be depiced from the below simulated results.

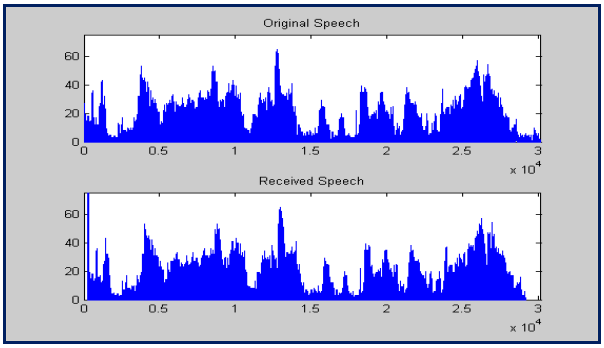

Fig-12: Output Speech with MIMO-Alamouti

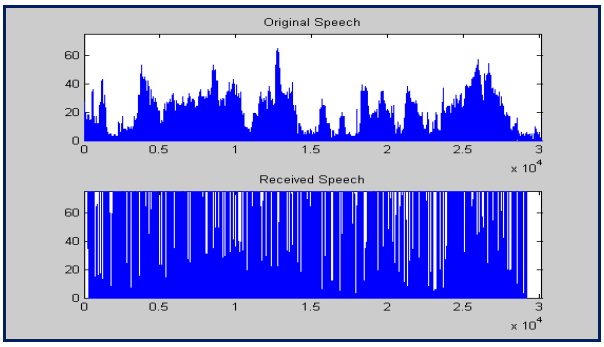

Fig-13: Output Speech with MIMO-VBLAST

With the simulation of WiMAX-Hybrid MIMO model, both the separate advantages of previous two models can be achieved in the single model i.e. improvement in data rate and improvement in BER.

V. CONCLUSION

With the implementation of Hybrid-MIMO structure in WiMAX standard, the whole capacity of the system will improve considerably in terms of Bit Error rate and data rate. With traditional WiMAX system that utilizes single antenna transmitter and receiver system, due to multi path structure of wireless channel, the error rate is high, while with the implementation of Alamouti and VBLAST structure in WiMAX, the BER will improve considerably from and subsequently data rate would be much higher as four antennas will transmit different signals simultaneously.

VI. FUTURE WORK

As this design includes the switch which can connect any of the diversity approach to achieve the advantage of improved BER or improved dara rate, for future aspect, the model can be made auto adaptable to sense the channel behavior automatically as and when required.

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