THE WiMAX GENERIC PDU FOR PHYSICAL LAYER PROCESS

Mr. Prakash M. Vora,
PhD. Research Student,
C.U.Shah University, C.U.Shah college of MCA, Wadhwan City, India.

ABSTRACT

The major trend that is already emerging is the migration of mobile network. The next generation of wireless systems, i.e. 4G systems will use new spectrum and emerging wireless air interfaces that will provide a very high bandwidth of 10+ Mbps. WiMAX is an advanced technology, it is optimized for high-speed data and should help spur innovation in services, content, and new mobile devices like, fixed and mobile applications based on an open standard designed to help deliver ubiquitous, high-throughput, broadband wireless services at a low cost flexible way. In this paper we deal with the physical layer of WiMAX system. This model is very useful to analyse the WiMAX system. The model presented in this paper built with generic MAC PDU processed by the Physical Layer using displayed time-scatter plots for 10, 20 and 30dB time-scatter plot for the output from the transmitter and the transmitted signal.

Keywords-- Convolution Coding, OFDM, Physical Layer, WiMAX.

I. Introduction.

The World wide interoperability for Microwave Access (WiMAX) Forum has begun certifying broadband wireless products for interoperability and compliance with a standard a broad industry consortium. WiMAX is based on wireless metropolitan area networking (WMAN) standards developed by the IEEE 802.16 group and adopted by both IEEE and the ETSI HIPERMAN group. In this paper, we present a concise of the emerging WiMAX solution for broadband wireless. The purpose here is to provide an executive summary, the salient features of WiMAX model with the physical and MAC-layer characteristics of WiMAX.

IEEE 802.16 Wireless MAN has a connection-oriented MAC and PHY is based on non-line of sight radio operation in 2-11 GHz. For licensed bands, channel bandwidth will be limited to the regulatory provisioned bandwidth divided by any power of 2, no less than 1.25MHz.

Three technologies have been defined like single carrier (SC), orthogonal frequency division multiplexing (OFDM) and orthogonal frequency division multiple access (OFDMA).

We develop a model for WiMAX using convolution coding techniques for AMC PDU process in our major paper. If a model for a system is developed after the design phase and tested correctly then early detection of a problem with the We develop a model for WiMAX using convolution coding techniques for AMC PDU process in our major paper. If a model for a system is developed after the design phase and tested correctly then early detection of a problem with the design is possible. This will reduce the time and cost to change the design at the later stages of the development. Once a model is built, tested and verified against a set criterion then using tools like Simulink and Matlab could be helpful in generating the code and exporting the model in suitable formats for implementation in hardware processors.

Models for other IEEE standards such as Bluetooth and Wireless LAN have been developed in the past using Matlab. There was a need to build a model for the WiMAX on similar lines to fill the gap.

II. THE WiMAX MODEL

The Model for the WiMAX is built from the standard documents. The model implemented in this paper is based on the WiMAX which has the following characteristics on the overall project development lifecycle .

Table-1 *THE CHARACTERISTICS OF THE OVERALL WIMAX MODEL DEVELOPMENT LIFE CYCLE*

Standard	IEEE 802.16e
Carrier Frequency	Below 11 GHz
Frequency Band	2.5 GHz, 3.5 GHz, 5.7 GHz,
Radio Technology	OFDM and OFDMA
Bandwidth	1.5 MHz to 20 MHz
Data Rate	70 Mbps
Distance	10 km

GHz= gigahertz, OFDMA= Orthogonal Frequency Division Multiplexing Access, MHz= Mega Hertz, Mbps= Megabits per seconds, km=kilometer.

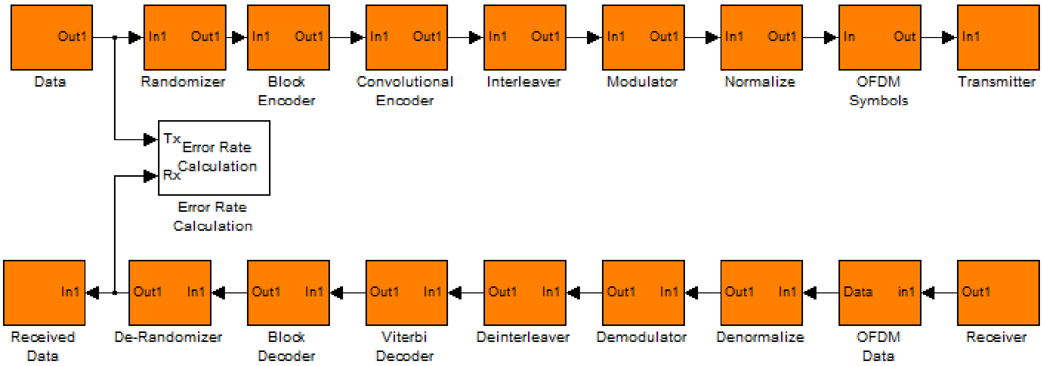

Figure 1 : WiMAX Physical Layer model

The Model itself consists of three main components namely transmitter, receiver and channel. Transmitter and receiver components consist of channel coding and modulation sub-components whereas channel is modelled as AWGN.

TABLE - 2
PARAMETERS FOR WIMAX MODEL

Scenario	16-Channel Full Bandwidth
Modulation	QPSK
RS Code Rate	3/4
CC Code Rate	1/2

QPSK = quadrature phase shift keying, RS = reed-solomon, CC = convolution coding.

I. CHANNEL CODING

Channel coding can be described as the transforming of signals to improve communications performance by increasing the robustness against channel impairments such as noise, interference and fading. The radio link is a rapidly changing link, often suffering from great interference. Channel coding, main tasks are to check and to correct the transmission errors of WiMax systems, must have a excellent performance in order to sustain high data rates. The 802.16 each channel coding chain is collected of three steps: Randomiser, Forward Error Correction (FEC) and Interleaving as per in figure 2. They are applied in this order at transmission. The corresponding operations at the receiver are applied in reverse order.

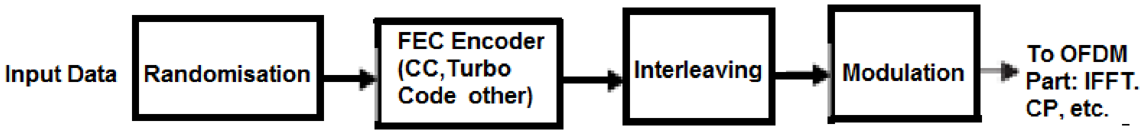

Fig. 2. OFDM physical transmission channel

A. *Randomization*

Randomisation starts protection by information-theoretic vagueness, avoiding long sequences of successive ones or successive zeros. It is useful for avoiding non-centred data sequences. Data randomisation is performed on each downlink and uplink burst of data.

Randomizer operates on a bit by bit basis. The purpose of the scrambled data is to convert long sequences of O's or 1's in a random sequence to improve the coding performance.

The Pseudo-Random Binary Sequence (PRBS) generator is used for randomisation is shown as per Figure 3. The generator defined for the randomizer is given by

$$1+X^{14}+X^{15} \qquad (1)$$

The bits issued from the randomiser shall be applied to encoder.

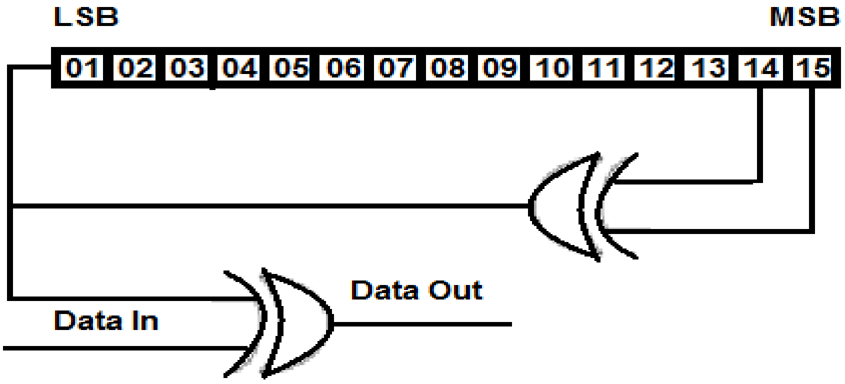

Fig. 3. Data Randomizer

A. *Forward Error Correction (FEC)*

Forward Error Correction is done on both the uplink and the downlink bursts and consists of concatenation of Reed-Solomon Outer Code and a rate compatible Convolutional Inner Code.

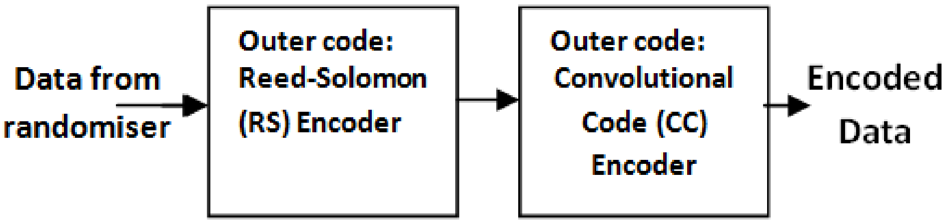

Fig. 4. Channel Coding

For OFDM physical, the RS-CC encoding is perform by first passing the data in block format through the RS encoder and then passing it through a convolutional encoder (Figure 4).

1) *Reed-Solomon encoding*

The purpose of using Reed-Solomon code to the data is to add redundancy to the data sequence. This redundancy addition helps in correcting block errors that occur during transmission of the signal.

A Reed–Solomon code is specified as RS(N,K) with T-bit symbols. The data points are sent as encoded blocks. The total number of T-bit symbols in an encoded block is $N = 2^T-1$. The number K, K < N, of uncoded data symbols in the block is a design parameter. Then, the number of parity symbols added is N > K symbols (of T-bits each). The RS decoder can correct up to (N - K)/2 symbols that contain an error in the encoded block. WiMAX uses a fixed RS Encoding technique based on GF(2^8) which is denoted as RS (N = *255,* K = 239,T =8).

Eight tail bits are added to the data just before it is presented to the Reed Solomon Encoder stage. This stage requires two polynomials for its operation called code generator polynomial g(x) and field generator polynomial p(x). The code generator polynomial is used for generating the Galois Field Array whereas the field generator polynomial is used to calculate the redundant information bits which are appended at the start of the output data.

Where:
N = Number of Bytes after encoding
K = Data Bytes before encoding
T = Number of bytes that can be corrected

The following polynomials are used to generate systematic code:

Code generator polynomial:

$g(x) = (x - \lambda^0)(x - \lambda^1)(x - \lambda^2)\ldots(x \_ - \lambda^{2T-1}),\ \lambda = 02HEX$--(2)

Field generator polynomial:

$p(x) = x^8 + x^4 + x^3 + x^2 + 1$ (3)

2) *Convolutional Encoding*

Convolutional codes are used to correct the random errors in the data transmission. A convolutional code is a type of FEC code that is specified by CC(m, n, k), in which each in-bit information symbol to be encoded is transformed into an n-bit symbol, where m/n is the code rate (n > m) and the transformation is a function of the last k information symbols, where k is the constraint length of the code.

To encode data, start with k memory registers, each holding 1 input bit. All memory registers start with a value of 0. The encoder has n modulo-2 adders, and n generator polynomials. In WiMAX Physical Layer each RS block is encoded by the binary convolutional encoder, which has a code rate of 1/2 and a constraint length equal to 7. This encoder has two binary adders X and Y and uses two generator polynomials, A and B.

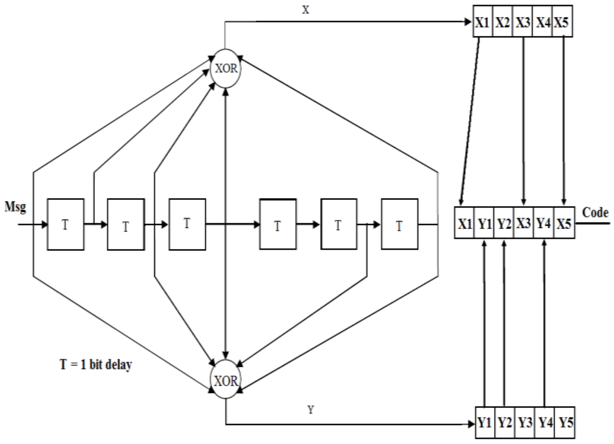

Fig. 5. FEC convolution and encoding

These generator polynomial codes are:

A = 171 octal = 1111001 binary for X (4)

B = 133 octal = 1011011 binary for Y (5)

The output of the convolutional encoder is then punctured to remove the additional bits from the encoded stream. The number of bits removed is dependent on the code rate used one for each adder.

II. INTERLEAVING

Interleaving is used to protect the transmission against long sequences of consecutive errors, which are very difficult to correct. These long sequences of error may affect a lot of bits in a row and can then cause many transmitted burst losses. Interleaving, by including some diversity, can facilitate error correction. The encoded data bits are interleaved by a block interleaver with a block size corresponding to the number of coded bits per allocated subchannels per OFDM symbol. The interleaver is made of two steps:

- Distribute the coded bits over subcarriers.

A first permutation ensures that adjacent coded bits are mapped on to nonadjacent subcarriers.

- The second permutation insures that adjacent coded bits are mapped alternately on to less or more significant bits of the constellation, thus avoiding long runs of bits of low reliability.

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the allocated subchannels per OFDM symbol, Ncbps.the interleaver is defined by a two step permutation. the first ensures that adjacent coded bits are mapped onto nonadjacent subcarriers.the second permutation insures that adjacent coded bits are mapped alternatively onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits.

Let N_{cpc} be the number of coded bits per subcarrier,i.e.1,2,4 or 6 for BPSK,QPSK,16-QAM,or 64-QAM,respectively.Let s=ceil($N_{cpc}/2$).within a block of N_{cbps} bits at transmission, let k be the index of the coded bit before the first permutation; f_k be the index of that coded bit after the first and before the second permutation; and let s_k be the index after the second permutation, just prior to modulation mapping.

The first and second permutation is defined by equ. (1), (2)

$f_k = (N_{cbps}/12).k_{mod12}+floor(k/2) \quad k = 0,1,2,\ldots ..N_{cbps}-1 \quad (1)$

$s_k = s.floor(f_k/s) + (m_k +N_{cbps} - floor(12.m_k/N_{cbps}))_{mod(s)}$

$k=0,1,2,\ldots \ldots N_{cbps}-1 \quad (2)$

where, N_{cpc}= Number of coded bits per carrier ,

N_{cbps}= Number of coded bits per symbol,

K=Index of coded bits before first permutation,

m_k=Index of coded bits after first permutation,

j_k=Index of coded bits after second permutation

The De-interleaver, which performs the inverse operation, is also defined by two permutation. Within a received block of N_{cbps} bits, let j be the index of a received bit before the first permutation; f_j be the index of that bit after the first and before the second permutation; and let s_j be the index of that bit after the second permutation, just prior to delivering the block to the decoder.

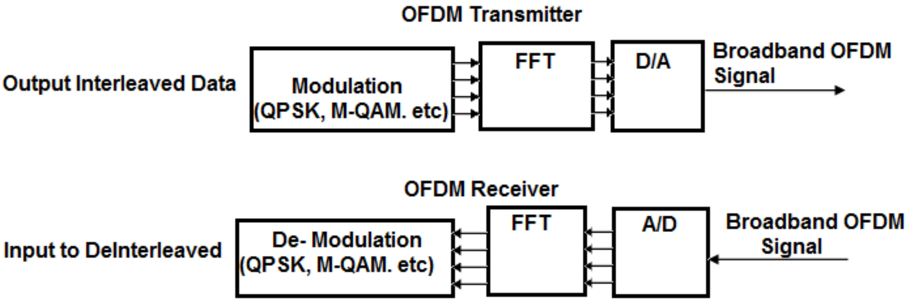

Fig. 6. FEC convolution and encoding

The first and second permutation is defined by equ. (3), (4)

f_j = s.floor(j/s)+(j + floor(12.j/N_{cbps}))$_{mod(s)}$

where j=0,1,… ..N_{cbps}-1 (3)

s_j = 12.fj – (N_{cbps}-1).floor(12.fj/N_{cbps})

where j=0,1,2… … ..N_{cbps}-1 (4)

where, N_{cpc} = Number of coded bits per carrier

N_{cbps} = Number of coded bits per symbol

K = Index of coded bits before first permutation

m_k = Index of coded bits after first permutation

j_k = Index of coded bits after second permutation

The first permutation in the de-interleaver is the inverse of the second permutation in the interleaver, and conversely. Below table show the bit interleaver sizes as function of modulation and coding. The first bit out of the interleaver shall map to th MSB in the constellation.

TABLE – 3 BLOCK SIZES OF THE BIT INTERLEAVER

	Default(16 subchannels)	8 subchannels	4 subchannels	2 Subchannels	1 subchannels
	N_{cbps}				

BPSK	192	96	48	24	12
QPSK	384	192	96	48	24
16-QAM	768	384	192	96	48
64-QAM	1152	576	268	144	72

III. MODULATION

As for all recent communication systems, WiMAX/802.16 uses digital modulation. Four modulations are supported by the IEEE 802.16 standard: BPSK, QPSK, 16-QAM and 64-QAM. In this section the modulations used in the OFDM and OFDMA Physical layers are introduced for modulations. In the modulation phase the coded bits are mapped to the IQ constellation, starting with carrier number -100 on up to carrier number +100. To simplify transmitter and receiver designs, all symbols in the FCH and DL data bursts are transmitted with equal power by using a normalization factor.

IV. OFDM SYSTEM IMPLEMENTATION

The digital implementation of OFDM system is achieved through the mathematical operations called Discrete Fourier Transform (DFT) and its counterpart Inverse Discrete Fourier Transform (IDFT). These two operations are extensively used for transforming data between the time domain and frequency domain. In case of OFDM, these transforms can be seen as mapping data onto orthogonal subcarriers. In practice, OFDM systems employ combination of fast fourier transform (FFT) and Inverse fast fourier transform (IFFT) blocks which are mathematical equivalent version of the DFT and IDFT.

At the transmitter side, an OFDM system treats the source symbols as though they are in the frequency domain. These symbols are feed to an IFFT block which brings the signal into the time domain. If the N numbers of subcarriers are chosen for the system, the basis functions for the IFFT are N orthogonal sinusoids of distinct frequency and IFFT receive N symbols at a time. Each of N complex valued input symbols determines both the amplitude and phase of the sinusoid for that subcarrier.

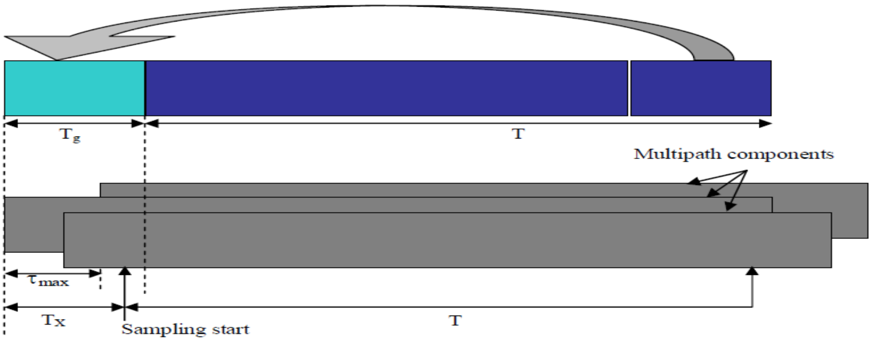

Fig. 7. Cyclic Prefix in OFDM

The output of the IFFT is the summation of all N sinusoids and makes up a single OFDM symbol. The length of the OFDM symbol is NT where T is the IFFT input symbol period. In this way, IFFT block provides a simple way to modulate data onto N orthogonal subcarriers. At the receiver side, The FFT block performs the reverse process on the received signal and bring it back to frequency domain.

A. Cyclic Prefix Addition

The subcarrier orthogonality of an OFDM system can be jeopardized when passes through a multipath channel. CP is used to combat ISI and ICI introduced by the multipath channel. CP is a copy of the last part of OFDM symbol which is appended to the front of transmitted OFDM symbol.

The length of the CP (T_g) must be chosen as longer than the maximum delay spread of the target multipath environment. Figure 6 depicts the benefits arise from CP addition, certain position within the cyclic prefix is chosen as the sampling starting point at the receiver, which satisfies the criteria $t_{max} < T_x < T_g$ where t_{max} is the maximum multipath spread. Once the above condition is satisfied, there is no ISI since the previous symbol will only have effect over samples within $[0, t_{max}]$. And it is also clear from the figure that sampling period starting from T_x will encompass the contribution from all the multipath components so that all the samples experience the same channel and there is no ICI.

V. THE WIMAX MODEL TEST RESULTS AND PERFORMANCE

The WiMAX standard document provides several test cases and test vectors for each test case. Below are the test results for each component in hexadecimal format.

Data Payload from the MAC Layer (29 bytes frame)

45 29 C4 79 AD OF 55 28 AD 87 B5 76 IA 9C 80 50 45 lB 9F D9 2A 88 95 EB AE B5 2E 03 4F

Data Frame after Randomization Stage (35 bytes frame)

D4 BA A1 12 F2 74 96 3027 D4 88 9C 96 E3 A9 52 B3 15 AB FD 92 53 07 32 CO 62 48 FO 19 22 E0 91 62 IA CI

Data Frame after Reed-Solomon Encoding (40 bytes frame)

49 31 40 BF D4 BA A1 12 F2 74 96 30 27 D4 88 9C 96 E3 A9 52 B3 15 AB FD 9253 07 32 CO 62 48 FO 19 22 E0 91 62 1A C1 00

Data Frame after Convolutional Encoding (48 bytes frame)

3A SE E7 AE 49 9E 6F IC 6F Cl 28 BC BD AB 57 CD BC CD E3 A7 92 CA 92 C2 4D BC 8D 78 32 FB3 BF DF 23 ED8A 94 16 27 AS 65 CF 7D 16 7A 45 B8 09 CC

Data Frame after Interleaving (48 bytes frame)

77 FA 4F 17 4E 3E E6 70 E8 CD 3F 76 90 C4 2C DB3 F9 B7 F13 43 6C Fl 9A BD ED OA IC D8 lB EC 9B 30 15 BA DA 31 F5 50 49 7D 56 ED B4 88 CC 72 FC SC

Based on the model presented in this paper, and tests carried out, the performance was established based on 10 million symbols in each case. The performance is displayed in the following figure time-scatter plots for 10, 20 and 30dB; time-scatter plot for the output from the transmitter and the transmitted signal.

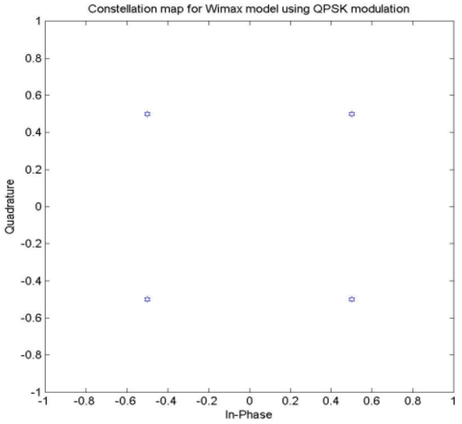	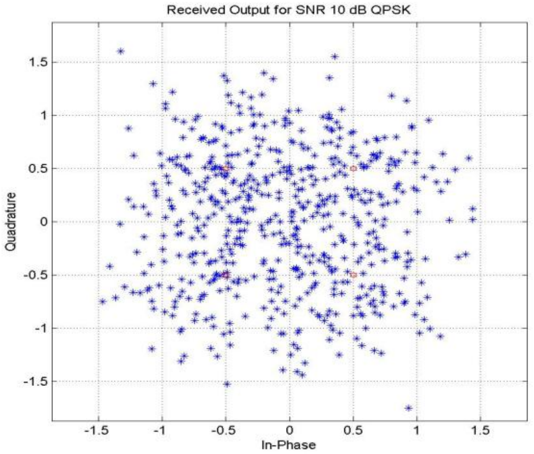
Fig. 8. Constellation diagram for QPSK modulation	Fig. 9. Received output for 10 dB SNR

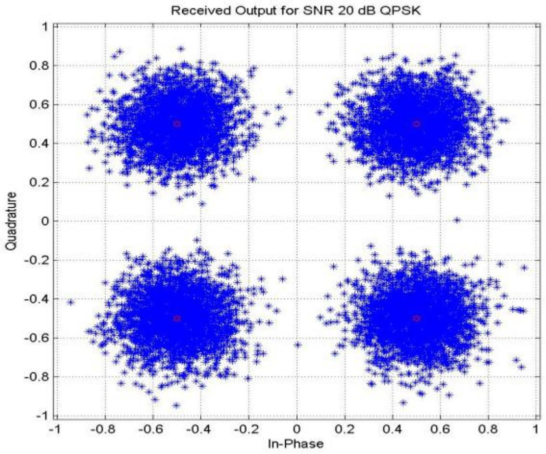

Fig. 10. Received output for 20 dB SNR

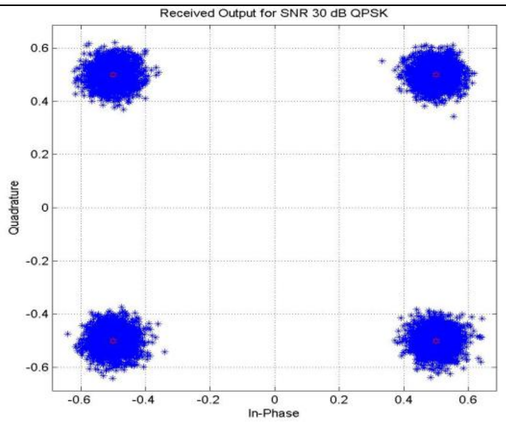

Fig. 11. Received output for 30 dB SNR

The time-scatter plots demonstrate the scattering of the transmitted and received signals at different values of the Signal-to-Noise Ratios.

VI. CONCLUSION

The model built in this paper demonstrates the importance of modelling a system to understand its functionality. Tests can the carried out on the model to calculate the performance indicators. The results of the simulation from the models will enable the researchers to choose the best option for their requirements. As we increase the SNR then our received scattered data approaches to transmitted scattered data.

ACNOWLWDGEMENT

I am kindly thankful to almighty who has given me the potential to reach at this level. I am also thankful to my Principal sir and my HOD who has given me constant inspiration to participate in the conference of such a remarkable level. I am also thankful to all those people who had directly or indirectly helped me to prepare this paper. At last, I can’t forget to thank to my parent who give me constant motivation to do innovative things.

REFERENCES

[1] IEEE 802.16-2006: "IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems"

[2] Thesis: "Performance Evaluation of WiMAX/IEEE 802.16 OFDM Physical Layer" Mohammad Azizul Hasan, July 2007.

[3] ETSI TS 102 177 Version 1.3. 1, February 2006, "Broadband Radio Access Networks (BRAN); HiperMAN ; Physical (PHY) Layer"

[4] Practical Applications for Wireless Networks, Paris, 10 October 2006, lET Workshop 2006

[5] WiMAX and Mesh Networks, London, 14-15 June 2005, IEEE Seminar 2005.

[6] Nuaymi Loutfi, 2007, WiMAX Technology for Broadband Wireless Access, Wiley, London.

[7] Mathworks Whitepaper, 2006, "Creating an Executable Specification for WiMAX Standard"2. Oxford: Clarendon, 1892, pp. 68-73.