Performance of Space Time Block Coding in an IEEE 802.16-2004 OFDM Physical Link

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***Abstract*-This paper highlights the performance of Space Time Block Coding in an IEEE 802.16-2004 OFDM physical link. The evaluation was done by comparing the performance of the system which include Space Time Block Coding and with the system that exclude the Space Time Block Coding. The system parameters that were used in this study were the cyclic prefix (CP) factor which is 1/4, 1/8/, 1/16, 1/32 and a range of SNR which is -10 to 10. BER is evaluated from these parameters and compared between the two systems. This study has been done using MATLAB 7.5.0 (R2007b). The finding shows that the BER value is lowest in the system which has the Space Time Block Coding (STBC). Overall, it shows that with Space Time Block Coding, the performance of Wireless System is better by 99.97% with a cyclic prefix at 1/32.**

Keywords: Bit Error Rate (BER), Signal to Noise ratio (SNR), Space Time Block Coding (STBC), Othorgonal Frequency Division Multiplex (OFDM), Cyclic Prefix (CP).

I. INTRODUCTION

Space time block coding is extremely important in wireless transmission system in order to improve the reliability of data transmission. This research has been done to evaluate the performance of Space Time Block Coding in an IEEE 802.16-2004 OFDM physical link. The value of bit error rate (BER) has been taken in every cyclic prefix and has been compared which has the lowest value. The lowest value of BER indicates that it has the best quality of transmitting data. The model of IEEE 802.16-2004 without Space Time Block Coding also has been evaluated. The lowest BER between the specific cyclic prefix were then to be compared with the model which includes space time block coding.

The wireless technology system will be inefficient without the implementation of Space Time Block Coding. Study has shown that the application of Space Time Block Coding in wireless communication area improves the performance of transmitting data by maximizing rate and minimizing delay [1]. Some of the works on space time block coding focuses on improving the performance of existing system in terms of the probability of incorrectly detected data packets by employing extra transmits antenna, and other research capitalizes on the promises of information theory to use the extra antennas for increasing throughput [2]. So, this finding can help anyone who wish to design a wireless system which has the better performance in transmitting data and who wish to improve their design in wireless communication. This simulation using MATLAB is the best method in the first step in designing such system because of its low cost and ease of error detection and conclusion. .

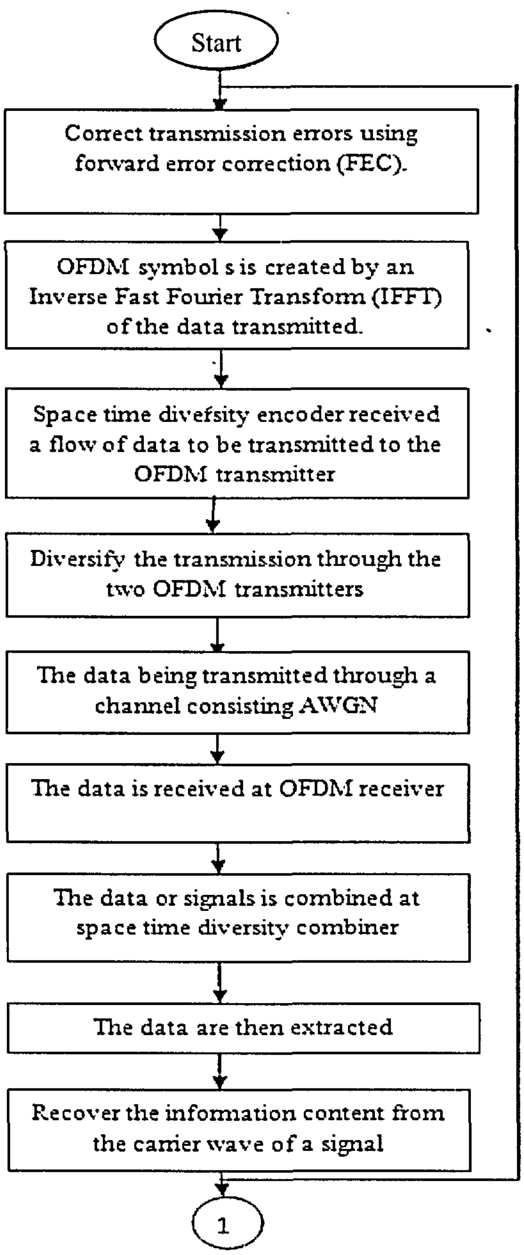
Alamouti STBC has been used in this study because it can provide diversity in time and space [3]. Delay spread from multipath signal propagation causes Inter-Symbol Interference (ISI) and Inter-Chip Interference (ICI) [4]. In order to preserve the orthogonality of subcarriers a Cyclic Prefix (CP) is introduced in front of every useful part of an OFDM symbol [5]. The CP in an OFDM symbol helps to remove the impact of multipath signal delay spread by making the OFDM symbol appear periodic in time [6]. CP extends the useful OFDM symbol duration by copying the last portion of the OFDM waveform to the front of the symbol [7]. Hence, in this scope of study, four different CP factors that are specified in 802.16-2004 has been used which are 1/4, 1/8, 1/16, 1/32. This factor is being simulated one at a time with a range of signal-to-noise ratio (SNR) to get the performance of bit-error-rate (BER). The range of

SNR that was used in this study was -10 to 10. Thus, whichever BER that has the smallest value among the CP factor indicates that the CP factor is ideal. The reason of determining the BER performance in different CP is to evaluate the performance of space time block coding in terms of diversity and coding gains. The higher the SNR value, the lower BER value will be obtained.

II. METHODOLOGY

This study was done by using MATLAB7.5.0 (R2007b). Simulation was chosen to be the primary tool for this study.

Figure 1 shows the flow chart of IEEE 802.16-2004 OFDM Physical link, including Space Time Block Coding. This procedure involved STBC implementation.



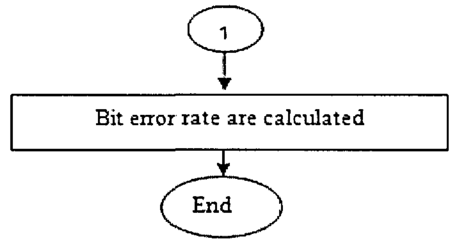
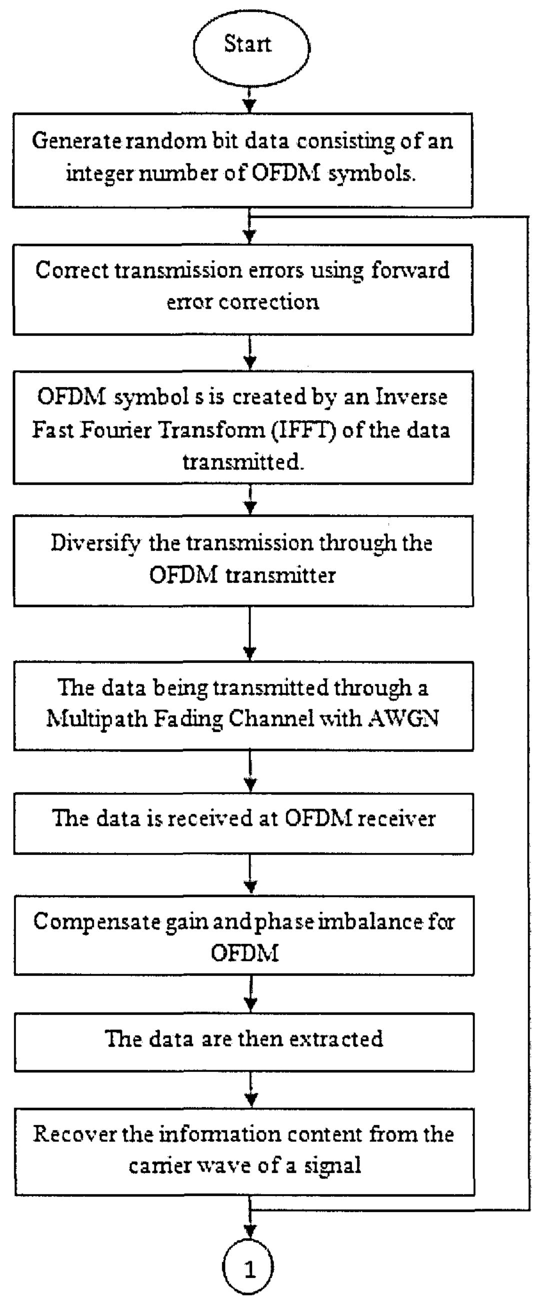


Figure 1 Flow chart of IEEE 802.16-2004 OFDM Physical link, including Space Time Block Coding

Figure 2 shows the flow chart of IEEE 802.16-2004 WirelessMan-OFDM Physical link. This procedure does not involved STBC implementation.



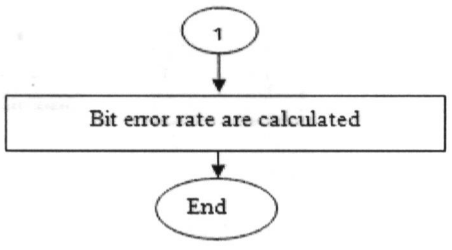


Figure 2 Flow chart of IEEE 802.16-2004 WirelessMan-OFDM Physical Link

A. Block Diagram

There are several blocks of components that were used in WMAN 802.16-2004 OFDM physical layer using two models which is one with STBC and one without, which has all the mandatory coding and modulation options.

The tasks performed in the communication system models include the generation of random bit data that models a downlink burst consisting of an integer number of OFDM symbols as shown in Figure 3. Prior to that, cyclic prefix factor ¼ was selected in the simulation settings block as shown in Figure 4. The data were then goes into FEC & Modulator for the modulation and error correcting purposes.

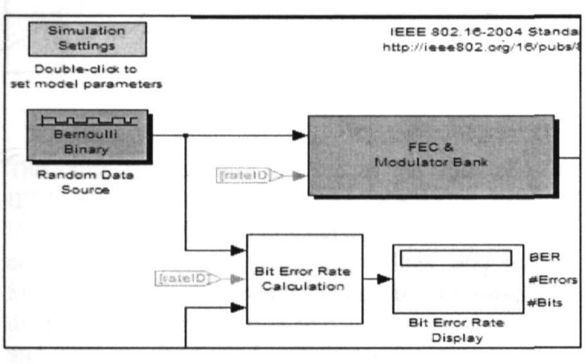


Figure 3

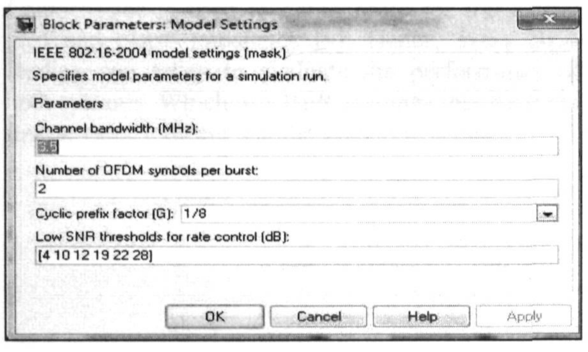


Figure 4

In Figure 5, the data from previous block goes into the IFFT Input Packing which produces the filtered signal [8]. Then, the data goes into the space-time block coding system which consists of space-time diversity encoder with two OFDM transmitters. The OFDM transmitters transmit data through AWGN channel as shown in Figure 6.

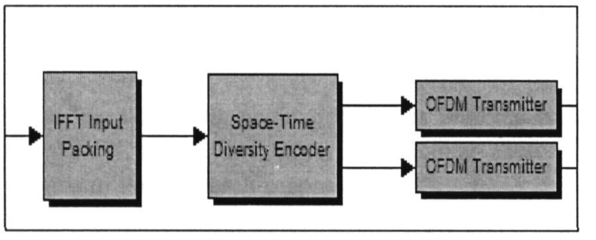


Figure 5

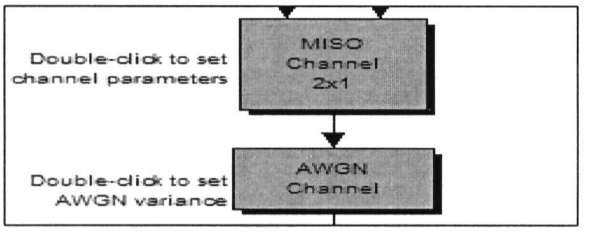


Figure 6

Figure 7 shows that SNR value can be inserted in the AWGN channel block. The range of SNR is -10 to 10 for every cyclic prefix factor.

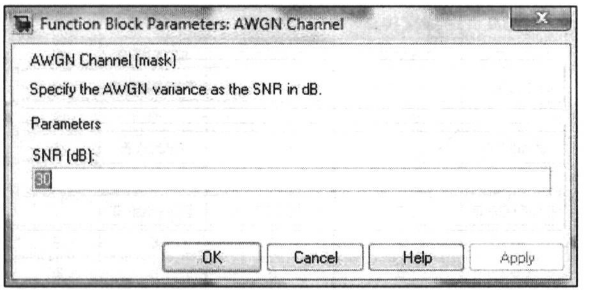


Figure 7

After the data has been passed through the AWGN channel, the data will be received at the OFDM receiver. In Figure 8, space-time diversity combiner combines all the data that has been received from the OFDM receiver. Then, the data carriers were extracted.

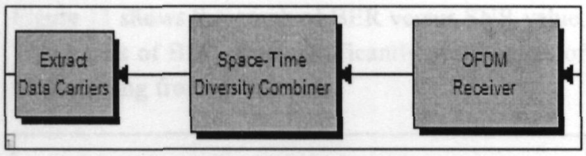


Figure 8

All the extracted data all goes to the demodulator & FEC Bank so that the data is demodulated and errors are corrected as shown in Figure 9. Finally, after each cyclic prefix factor (1/4, 1/8, 1/16, 1/32) has been simulated with the range of SNR (-10 to 10), the Bit Error Rate Calculation has been taken as shown in Figure 10.

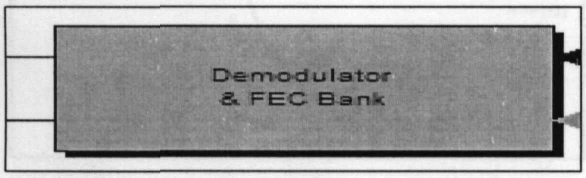


Figure 9

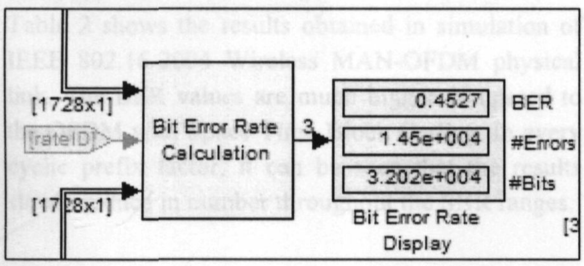


Figure 10

The same method was applied to the simulation of IEEE 802.16-2004 Wireless MAN-OFDM Physical Downlink. The differences between the two of them are that the second simulation does not include Space-Time Block Coding. Thus, in that simulation diagram, the difference is that it has one transmitter and one receiver, and consists of Gain & Phase Compensator after the receiver. The Gain & Phase Compensator is used to compensate for transmitter gain and phase imbalance [9]. Hence, every BER reading was taken to evaluate the performance of both systems. Whichever BER readings that have the lowest value indicate that the system is better.

III. RESULTS AND DISCUSSION

A. Results of BER in OFDM Physical Link with STBC and without STBC.

For every cyclic prefix factor that was simulated with the range of SNR, the readings of BER was taken. Table 1 shows the reading of BER of IEEE 802.16-2004 OFDM physical link which include Space Time Block Coding.

Table 1 shows that for every cyclic prefix, the BER value has very little slight differences between one another. It shows that when approaching SNR at range 8 to 10, the result is constant at 0.

Table 1

Table of BER value in OFDM Physical Link with STBC

SNR \ CP	1\4	1\8	1\16	1\32
-10	0.4953	0.5003	0.4939	0.4953
-9	0.4961	0.5007	0.501	0.4961
-8	0.4951	0.5025	0.4945	0.4951
-7	0.4991	0.4938	0.4957	0.4991
-6	0.49	0.4874	0.4913	0.49
-5	0.4791	0.4761	0.4791	0.4791
-4	0.4498	0.4527	0.455	0.4498
-3	0.3828	0.3858	0.3815	0.3828
-2	0.2686	0.2665	0.2614	0.2686
-1	0.1467	0.1452	0.1476	0.1467
0	0.05615	0.06009	0.05907	0.05615
1	0.0115	0.01431	0.01554	0.0115
2	0.002174	0.002655	0.002215	0.002174
3	0.0001144	3.123e-.005	8.861e-.005	0.0001144
4	0	3.123e-.005	0.01707	0
5	0.03455	0.04542	0.0312	0.03455
6	0.007027	0.009623	0.006447	0.007027
7	0.0002412	0.0004145	0	0.0002412
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0

Figure 11 shows the graph of BER versus SNR value. The results of BER drop significantly at the range of SNR starting from -5 onwards.

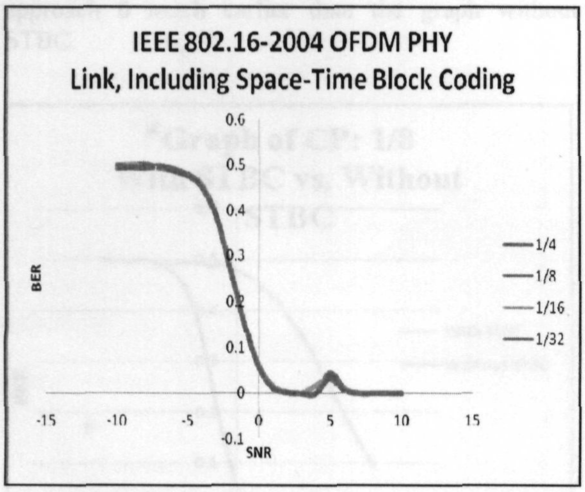


Figure 11

Table 2 shows the results obtained in simulation of IEEE 802.16-2004 Wireless MAN-OFDM physical link. The BER values are much bigger compared to the OFDM with Space Time Block Coding. In every cyclic prefix factor, it can be seen that the results slowly reduce in number throughout the SNR ranges.

Table 2
Table of BER value in OFDM Physical Link without STBC

SNR \ CP	1\4	1\8	1\16	1\32
-10	0.5009	0.4949	0.4956	0.495
-9	0.4979	0.498	0.4973	0.4997
-8	0.4964	0.5001	0.4939	0.496
-7	0.497	0.4979	0.4936	0.5009
-6	0.4972	0.4979	0.5003	0.5035
-5	0.4922	0.4976	0.4959	0.5044
-4	0.4927	0.4931	0.5004	0.4995
-3	0.4968	0.496	0.4975	0.4975
-2	0.4842	0.4905	0.4973	0.4977
-1	0.4887	0.4921	0.4858	0.4897
0	0.4763	0.4801	0.4823	0.4787
1	0.465	0.4672	0.4664	0.4693
2	0.4393	0.4404	0.4468	0.4532
3	0.4173	0.4261	0.4226	0.4231
4	0.3758	0.3887	0.3789	0.3794
5	0.3388	0.3447	0.3447	0.3358
6	0.2864	0.2817	0.2827	0.2901
7	0.2369	0.2326	0.2403	0.2395
8	0.1848	0.1747	0.1845	0.1825
9	0.1359	0.13	0.1345	0.1396
10	0.09136	0.09045	0.09505	0.0962

The graph in Figure 12 shows that for SNR between -10 to -3, the results seems contant but start to drop significantly between the SNR value of 3 to 10.

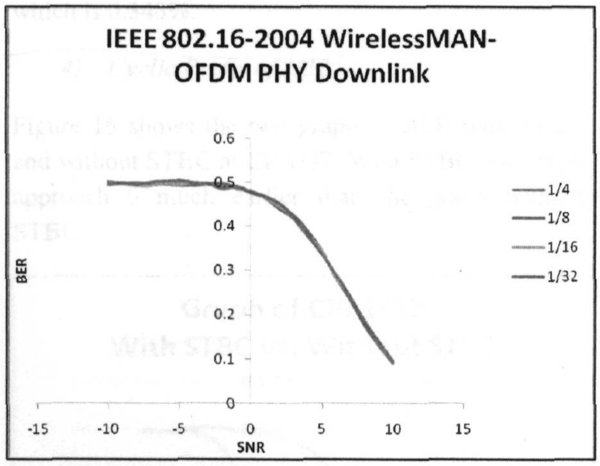


Figure 12 Graph of IEEE 802.16-2004 WirelessMan- OFDM physical link.

B. Comparisons of BER in Every Cyclic Prefix between OFDM Physical Link with STBC and without STBC.

1) Cyclic Prefix of ¼

Figure 13 shows the two graph of BER with STBC and without STBC at CP 1/4. With STBC, the graph approach 0 much earlier than the graph without STBC.

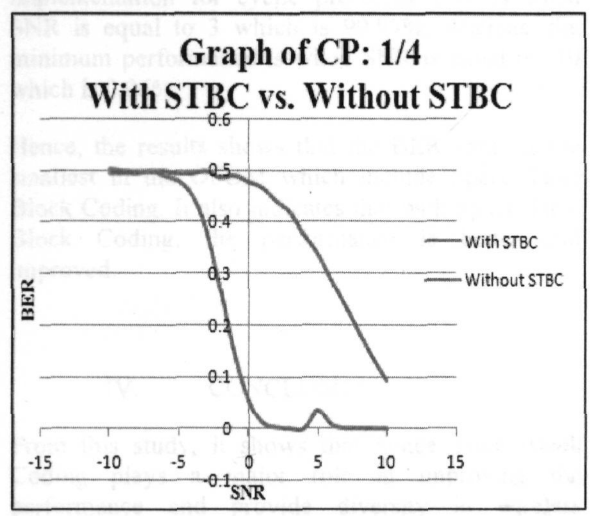


Figure 13 Graph of cyclic prefix ¼

The maximum improved performance of STBC implementation for cyclic prefix of ¼ is when SNR is equal to 7 which is 99.89%. whereas, the minimum performance is when SNR is equal to -8 which is 0.26%.

2) *Cyclic Prefix of 1/8*

Figure 14 shows the graph of BER with STBC and without STBC at CP 1/8. With STBC, the graph approach 0 much earlier than the graph without STBC.

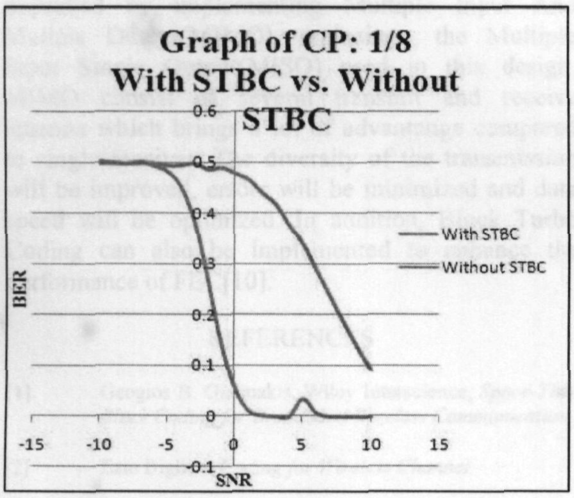


Figure 14 Graph of cyclic prefix 1/8

The maximum improved performance of STBC implementation for cyclic prefix of 1/8 is when SNR is equal to 7 which is 99.82%. whereas, the minimum performance is when SNR is equal to -8 which is 0.48%.

3) *Cyclic Prefix of 1/16*

Figure 15 shows the two graph of BER with STBC and without STBC at CP 1/16. With STBC, the graph approach 0 much earlier than the graph without STBC.

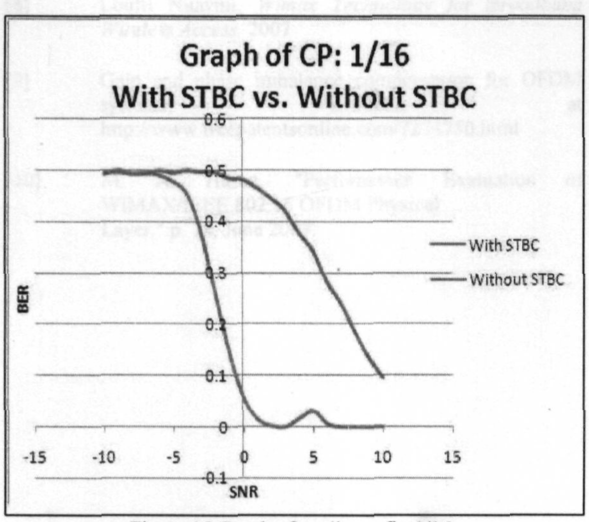


Figure 15 Graph of cyclic prefix 1/16

The maximum improved performance of STBC implementation for cyclic prefix of 1/16 is when SNR is equal to 2 which is 99.5%. whereas, the minimum performance is when SNR is equal to -10 which is 0.343%.

4) *Cyclic Prefix of 1/32*

Figure 16 shows the two graph of BER with STBC and without STBC at CP 1/32. With STBC, the graph approach 0 much earlier than the graph without STBC.

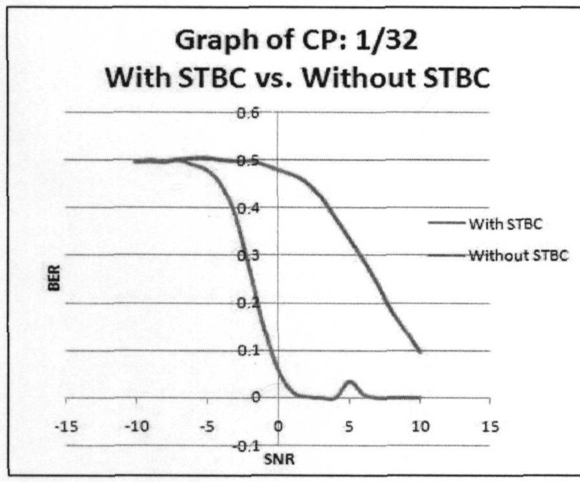


Figure 16 Graph of cyclic prefix 1/32

The maximum improved performance of STBC implementation for cyclic prefix of 1/32 is when SNR is equal to 3 which is 99.97%. whereas, the minimum performance is when SNR is equal to -10 which is 0.06%.

Hence, the results shows that the BER value is the smallest in the OFDM which include Space Time Block Coding. It also indicates that with Space Time Block Coding, the performance is better and improved.

IV. CONCLUSION

From this study, it shows that Space Time Block Coding plays a major role in improving the performance and provide diversity in wireless communication. With Space Time Block Coding in such system, BER performance can be reduced drastically compared to the system which does not have one. Other than that, from the findings, cyclic prefix does not have much influences in contributing the performance of BER. For both system, it can be seen that BER value remains mostly the same for every cylic prefix. The maximum improved performance for BER is when STBC are included and when the cyclic prefix is set at 1/32 which is 99.97%.

Hence, for future recommendation, the design can be improved by implementing Multiple Input And Muliple Output(MIMO), replacing the Multiple Input Single Output(MISO) used in this design. MIMO consist of several transmit and receive antenna which brings a lot of advantange compared to single receiver. The diversity of the transmission will be improved, errors will be minimized and data speed will be optimized. In addition, Block Turbo Coding can also be implemented to enhance the performance of FEC[10].

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