SIMULATION & PERFORMANCE OF SPACE TIME FREQUENCY BY USING TURBO CODES

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Abstract- **This paper highlights the simulation using Space Time Frequency Coding (STFC) in order to identify the performance capability of Turbo Code with using a Quaternary Phase Shift Keying (QPSK) *modulation technique.* Generally, Turbo Code as encoder is functioning to convert the input signal become into a binary form before the modulation happens. The project report focuses on the simulation by the matlab software. Upon this report, we will looking the performance of Turbo Codes as an encoder at the transmitter, and decoder at the receiver by using Space Time Frequency Code (STFC). Matlab version 7.5 is used to simulate the system. The model consists of transmitter, transmission channel and receiver.**

This paper proposes a class of full space diversity with full rate space time frequency codes. Parallel concatenated codes are designed to this project. A lot of theory proposed is employed to check the full space diversity of the codes. The simulations show that the space time frequency codes can take full advantage of space diversity and time diversity if they are available in the channels. This project involved with Additive White Gaussian Noise (AWGN) as a transmission channel. At the same time, we also study the robustness of performance by Turbo Codes and compare with the system which excludes the Turbo Code by generating the signal using a similar modulation technique (QPSK). Here, we can make some finding about the goodness of using Turbo Code in term of Bit Error Rate (BER) and identifying the performance capability of it system.

Keyword- **Space Time Frequency Coding (STFC), Quaternary Phase Shift Keying (QPSK), Additive White Gaussian Noise (AWGN), Bit Error Rate (BER)**

1.0 INTRODUCTION

The demand for wireless communications has experienced a large growth, which challenged the research community to discover new communication techniques and systems that are capable of providing high data rates. Wireless channels have many physical limitations, such as fading and interference, which prevent reliable communication. In order to combat these limitations and achieve the goal of reliable communication over the wireless links, Turbo code by implementation of space time frequency block coding is being used. In this report, we present a comprehensive study of turbo codes as an encoder and decoder for the systems with transmit and receive antenna diversity introduced in [1], [2].

1.1 TURBO CODES FOR ANTENNA DIVERSITY SYSTEMS

In this project, we describe the use of turbo code modulation for wireless communication systems with multiple transmit and receive antennas. Turbo code is functionality as an encoder that will encodes the signal before transmit via the transmission channel to the modulator.

The block diagram of the transmitter where a turbo code is used as a channel encoder is given in Figure 1.1a below.

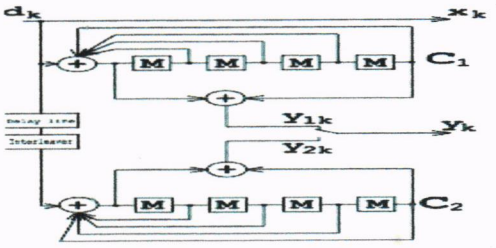

Figure 1.1a: Turbo code Encoder

The data is divided in blocks of N bits, and encoded by a binary turbo code. The turbo code consists of two systematic recursive convolutional codes concatenated in parallel via a pseudo-random interleaver [3]. The turbo coded bits are then interleaved and mapped to the appropriate constellation. We can obtain different spectral efficiencies by varying the code rate and the constellation. Since we assume block fading, the turbo code interleaver size is chosen to be a multiple of RJ.

1.2 MODULATION TECHNIQUE

Modulation is defined as a process of varying a periodic waveform in order to use that signal to convey a message [4]. The objective of the modulation in communication system is to translate the information signal into a form in which it can be transmitted over the channel. Three basic of *modulation technique* is Amplitude Shift Keying (ASK) and Binary Shift Keying (BPSK) which used for binary code in linear (amplitude and phase) modulation, also Frequency Shift Keying (FSK) which use for binary code in exponential (Frequency) modulation [5]. In this project, Quaternary Phase Shift Keying (QPSK) modulation technique is used to modulate the symbol (>1bit/symbol).

1.3 SPACE TIME FREQUENCY BLOCK CODING

Space Time Frequency Block Coding is one type of block code; a coding technique in the digital communication system that maximize diversity gain. For complex signal constellations, they showed that Alamouti's scheme is the only full-rate scheme for two transmit antennas .In this project, we study the performance of such a scheme with two receive antennas (i.e. a 2x2 system) with Additive White Gaussian Noise (AWGN). In the realistic scenario where the channel state information is not known at the receiver, this has to be extracted from the received signal. A simulation similar to the one described in the next section is employed here, which leads us to estimate the BER performance for a space-time frequency block coding system by using two transmit and two receive antennas.

1.4 MATLAB SIMULATION

Matlab is a software package for high performance in technical computing, engineering, integrating programming, visualisation and computation in a very user friendly environment. Best of all, it also provided extensibility and flexibility with its own high-level programming language. It has two major element that have contribute to it immense popularity; easy to use since data can easily entered especially for algorithms that are adaptable to a table format, and it include high level command for two dimensional visualization and presentation graph [6]. In this project, all the simulation was performed by automation programs, which were created by us. The whole simulation program was divided in sub-function, which was built in M-files form, *.M extension.

1.5 ADDITIVE WHITE GAUSSIAN NOISE CHANNEL (AWGN)

In communication, AWGN is one in which the only impairment is the linear addition of wideband or white noise with a constant spectral density (expressed as watts of bandwidth) and a Gaussian distribution of amplitude. The model does not account for phenomena of fading, interference, nonlinearity or dispersion. Wideband Gaussian noise comes from many natural sources, such as the thermal vibration of atoms in antennas, shot noise, black body radiation from the earth and other warm object, and from celestial sources such as the sun. The AWGN is a good model for many satellite and deep space communication links. It is not good model for most terrestrial link because of multipath, terrain blocking and, interference. However terrestrial path modelling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self interferences that modern radio system encounter in terrestrial operation [7].

2.0 OBJECTIVE

By using turbo codes and stimulate the input signal required by looking the performance which will get the maximum diversity in space time frequency block coding are proposed to get a lot of benefits. In term of bandwidth, we are required to get a small bandwidth. This is also preventing a higher cost of installing and generating the signalling which will cost by the provider to the subscribers. The objective of by using this technique also, it is to increase the level of speediness of the transmitting the signal. Nowadays, it becomes a requirement to have some methods or technique that can set up the level of speediness. Many providers are willing to invest a bunch of money to get the best performance. Otherwise, they will be left behind from the growth of technologies

On the other hand, it will reduce the bit error and get a maximum diversity order. They can provide a large data transmission. This will improve the capacity channel and the efficiency of the delivering the data through the wireless network. For an examples we can implemented this techniques in ASTRO, WIMAX, and one of the Military Communication application system. The transmission will make the signal faster and more efficient in term of signalling.

3.0 PROBLEM STATEMENT

Wireless communication has seen explosive growth in the past twenty years but the amount of radio spectrum suitable for wireless communication is limited. Consequently, more sophisticated technologies have to be employed to make better use of the radio spectrum while providing reliable service. One of the major challenges in wireless communication is overcoming channel fading caused by multi-path and movement in the radio link. The information theoretic study by Telatar [8] and Foschini and Gans [9] showed the enormous capacity promised by multiple antenna systems in such channels. These capacity results have motivated a new area in the design of channel codes.

Starting with the seminal paper by Tarokh et al. [10], there has been a surge of interests in the design of so called "space time frequency" codes attempting to harvest the available capacity. Space time frequency codes achieve the spatial diversity provided by multiple antennas properly designed codes. It has also been shown that temporal diversity can also be exploited in space time frequency codes to further the diversity advantage in demodulation. In addition to simple fading channels, we also study the robustness of the performance of space time frequency codes and space time codes in channels typical which will be encountered in wireless practice. The turbo codes of a wireless channel will greatly influence the performance of a space time frequency code [11]. We investigate the robustness by considering the model

proposed by Chen et al. [12] which captures many of the important characteristic of land mobile communications.

In this technical report also, we present the design of turbo codes for multiple antenna systems. Turbo codes are random like codes which have been shown to achieve near-capacity performance are dominated by the case when all the channels in the multiple antenna transmission schemes are in a deep fade. However, when the frame size is increased, the frame error rates of turbo codes stay the same due to the interleaving gain [13], [14].

4.0 METHODOLGY

4.1 BLOCK DIAGRAM AND FLOW CHART WITH TURBO CODE

Transmitter with Space Time Frequency coding by include turbo code. Input message is set to be random.

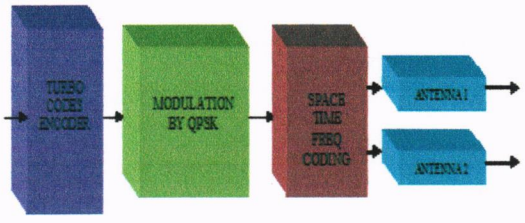

Figure 4.1a

Receiver with Space Time Frequency Coding by includes turbo code.

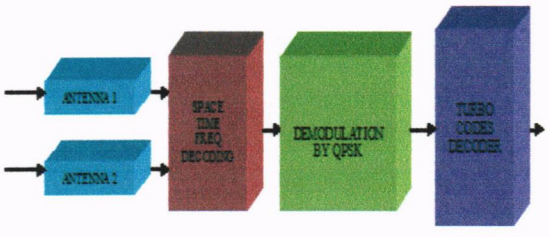

Figure 4.1b

Block diagram in both figure shows the overall stage that involved in the simulation process. The input message in (Figure 4.1a) is set to be random.

At the encode stage (Figure 4.1a), the information signal, k will be expand to n signal by using the turbo codes. All the codeword length then is modulated using by using QPSK technique. The objective is to change the digital signal to analog signal before transmit to space time frequency coding. The received modulated signal is then converted from analog to digital signal in order to obtain the codeword by using QPSK technique modulation method as transmitter. Next a received codeword will pass through the decoding stage to obtain the k information signal (Figure 4.1b).

Finally, the output message is compared with the input message to evaluate the performance of the system with the effect of noise in term of Bit Error Rate (BER). Figure4.1c below shows the complete flowchart of the overall simulation process.

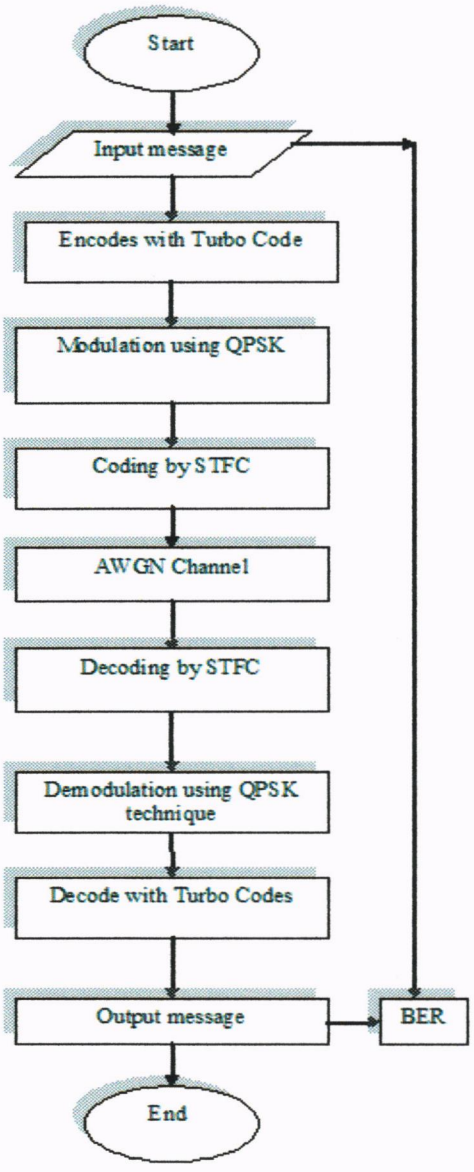

Figure 4.1c: Flow Chart

4.2 BLOCK DIAGRAM AND FLOW CHART WITHOUT TURBO CODE

To meet the project expectation with stimulate and discover the performance of the Turbo Code by using the Space Time Frequency Coding itself, this analysis need to be continued again by excluded Turbo Code and repeats the same process like a previous mentioned. Similar process will happens due to this signalling except there are not represent Turbo Code as an encoder and decoder.

Transmitter with Space Time Frequency coding by exclude turbo code. Input message is set to be random.

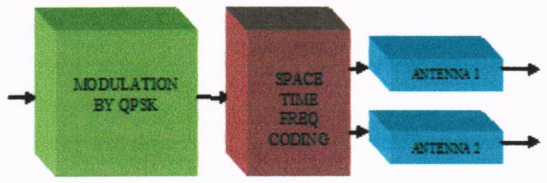

Figure4.2a

Receiver with Space Time Frequency coding by exclude turbo code.

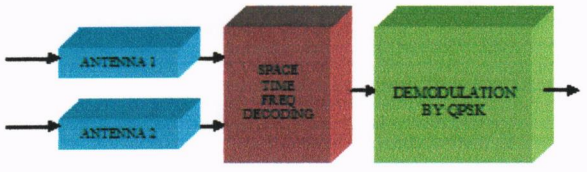

Figure4.2b

Figure4.2c below shows the complete flowchart of the overall simulation process.

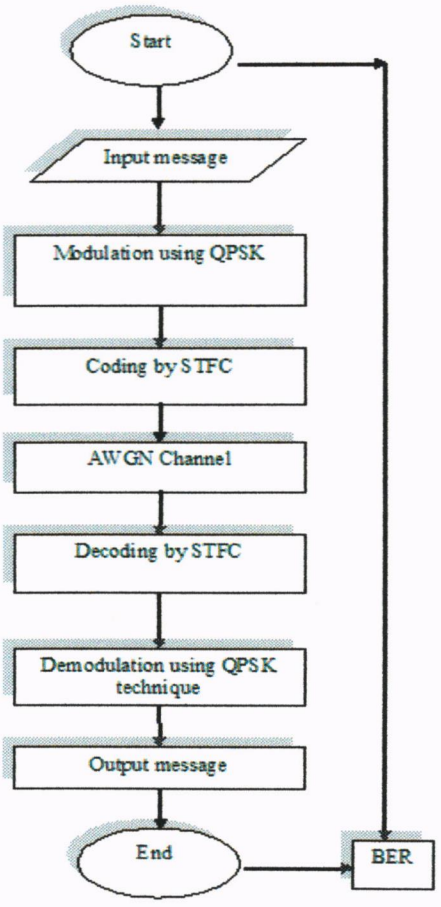

Figure 4.2c

4.3 RESULT AND ANALYSIS

This project model consists of transmitter part, communication channel and receiver part. After running the program using Matlab version 7.5, the result are obtained. Transmitter involved the process of encoding using Turbo Code and modulation the signal using Quaternary Phase Shift Keying (QPSK). Then the modulated signal will be decode the modulated signal with Space Time Frequency block Coding (STFC), after that the signal is transmit via communication channel where the signal is added with Additive White Gaussian Noise (AWGN). The receiver involved the process of demodulating the signal (to convert the analogue signal to digital signal) in order to get the original message.

Again we can scrutinize the output message by comparing the Bit Error Rate of these two different input message systems with using either Turbo Code or without Turbo Code. By then, we can make some finale postulation about the performance of the Turbo Code itself by differentiate the result in term of Bit Error Rate value and Eb/No (dB). Finally, from these two dissimilar processes, the performance of the system can be analysed by comparing with these two different input messages by simulated the system program in Matlab software. For overall simulation between using Turbo Code or without Turbo Code in Space Time Frequency Coding, there are significantly approved that turbo code is required to be used in the system accordingly to detect and correct the error of the signal to get a better performance and the maximum diversity in space time frequency block coding to obtain our project objective.

Here, some of the results which will be take parts in simulating the whole process of the programming to determine the project requirement.

STFC with using Turbo Code:
Random binary data;

```
g = [ 1 1 1;
      1 0 1 ];
```

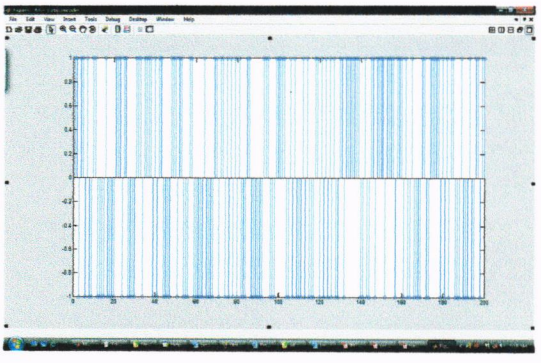

Figure 4.3a: Encoded signal at Turbo Code

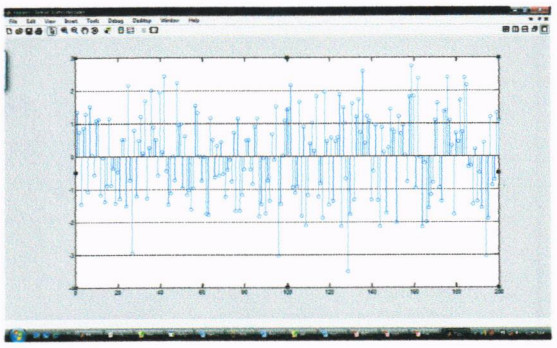

Figure 4.3a: Decoded signal at Turbo Code

STFC wihout using turbo code:
Random binary data;

0	0
1	1
0	0

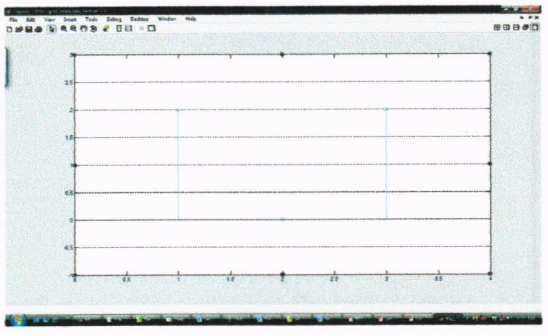

Figure 4.3c: Random signal for QPSK modulation

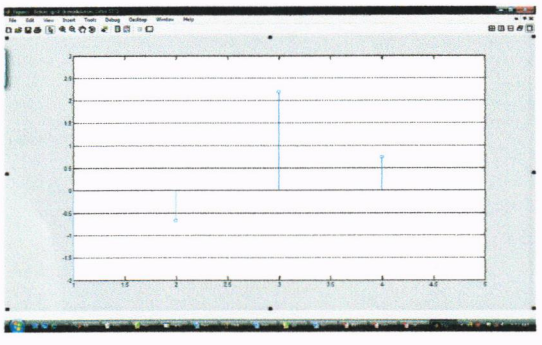

Figure 4.3d: Random signal for STFC

4.4 PERFORMANCE RESULT

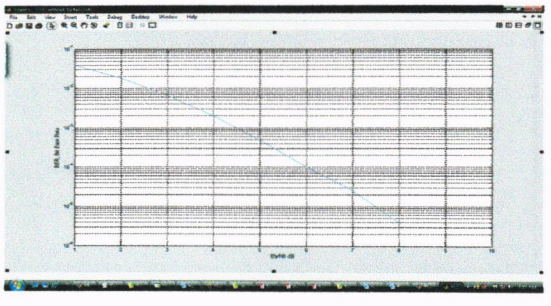

Figure 4.4a: Simulated performance without Turbo Code

Figure 4.4a shows the simulated performance of Space Time Frequency Coding by not using Turbo code. The BER performance is worst compared to the performance as shown in figure 4.4b.

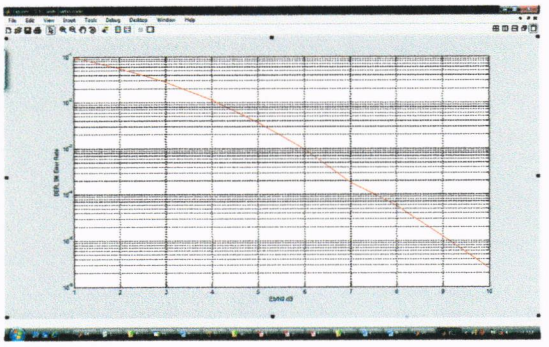

Figure 4.4b: Simulated performance with Turbo Code

Figure 4.4b shows the simulated performance of Space Time Frequency Coding by using Turbo Code. By making the comparison between these two figures, the outcome being the performance of the figure 4.4b is better compared to the performance in figure 4.4a. Thus, from these two results, it can conclude that performance of the Space Time Frequency coding will be better when using the Turbo code as an encoder and decoder.

To prove these two performances, the result is then compared with the graph of Bit Error Rate Vs Eb/No Performance with several of error correction capabilities that taken in book [15]. We can justify that it is much better when using the Turbo Code where it is capable to correct and detect an error in efficiently.

It also been shown that temporal diversity can also be exploited in space time frequency codes to further the diversity advantage in demodulation. It is proved that Turbo codes are random like codes which have been shown to achieve near-capacity performance which dominated by the case when all the channels in the multiple antenna transmission schemes are in a deep fade.

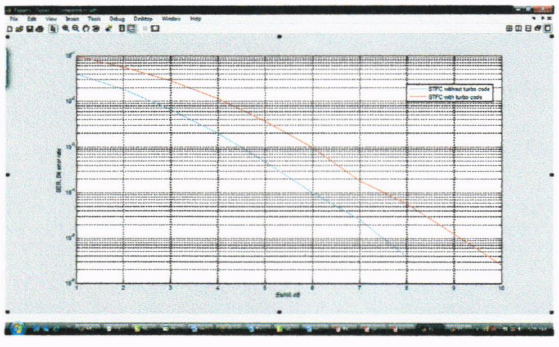

Figure 4.4c: Simulated performance for both channels

4.5 TABULATED PERFORMANCE RESULT

Term / value	Eb/No (dB)							
	1dB	2dB	3dB	4dB	5dB	6dB	7dB	8dB
STFC With Turbo Code	$9x10^{-2}$	$3.5x10^{-2}$	$1.8x10^{-2}$	$1.2x10^{-2}$	$2.5x10^{-3}$	10^{-3}	$1x10^{-4}$	$3x10^{-5}$
STFC Without Turbo Code	$3x10^{-2}$	$1x10^{-2}$	$5x10^{-3}$	$1x10^{-3}$	$4x10^{-4}$	10^{-4}	$1.5x10^{-5}$	$3x10^{-6}$

Table 4.5a

Term / value	Bit Error Rate (BER)				
	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}
STFC With Turbo Code	1dB	4.1dB	6dB	7.5dB	9dB
STFC Without Turbo Code	no value	2.6dB	4.5dB	6dB	7.5dB

Table 4.5b

Both tables above describe the performance comparison between using Turbo Code when transmit the signal and excluded the Turbo Code due the signalling. From the result obtained, we can see that, performance of the Space Time Frequency Coding will be better by using the Turbo Code in the transmission medium. The bit of error by placed the turbo code in the system will be smaller when compared to the system that not using turbo code. Besides that, when the BER at 10^{-2}, the Eb/No in term of dB is 4.1dB with using Turbo Code compared to the system which not using Turbo code will be smaller indicate nearly to 2.6dB. From this tabulated performance table also, we can make some observation that the Eb/No (dB) will be bigger when the Bit Error Rate is started to decrease from the value of 10^{-1} to 10^{-6}.

5.0 DISCUSSION

From the observation and analysis of this project, if the Turbo Code is being used as an encoder, a better performance will be produce and get the maximum diversity in space time frequency block coding. By this also, it will reduce the bit error and get a maximum diversity order. They can provide a large data transmission. From the analysis that have being made, we can easily proved this kind of method which can improve the capacity channel and the efficiency of the delivering the data through the wireless network. From this result obtained also we can describe that when using a Turbo Code, it will gain a bigger Eb/No which is manipulated in term of dB. The Bit error Rate; is an empirical (historical) record of a system's actual bit error performance and for QPSK bit error performance is directly related to the distance between points on a signal state space. Related to this project, we can discussed that the performance of error in Turbo Code by assemble QPSK modulation is more reliable and this resulted with a good performance of signalling seemed to be in tabulated result in figure 4.5a and 4.5b compared to the system which not using Turbo Code.

Upon my project to be accomplished, there are a lot of things and subject can be discussed. For the turbo code programming, some of examples were taken from the internet. A lot of time required to study the code program wisely. Actually, we need to identify and understand the problem while generating the signal through the Turbo Code block. The input and the output signal also need to be precisely concerned when simulate the signal by Matlab software. From this project, we can study about gold key that generate by the Turbo Code which is the special code that only produce by Turbo Code. Turbo Code Only will generate the input signal and produce [1, -1] codeword. This is the uniqueness by using the turbo code to detect and correct the error accurately. In Space Time Frequency Coding we are introduced with the AWGN channel. We had encountered the problem by adding noise into the system. After all, we can conclude that, AWGN is very important to be considered in the transmission channel.

Although this project only considers QPSK modulation, it could be changed to other modulation such as BPSK and 8-PSK. The idea is the same, but some research need to be done and some modification of the program need to be carried out. However, some of the simulated result may not be obtained well in practical. Many assumptions had already been made before the simulation started. So, some adjustment and calibration is required before it can be applied in a real world situation.

6.0 CONCLUSION

The main target of this project is to stimulate the output signal of the space time frequency in term of performance which is based on the turbo codes. The objectives of the project are achieved from the software program in the Matlab program. Turbo codes is used to get high-performance error correction codes finding use in deep space satellite communications and other applications where designers seek to achieve maximal information transfer over a limited-bandwidth communication link in the presence of data-corrupting noise. Actually the turbo codes are replacing the convolutional codes. By the short convolutional codes that closely approach the theoretical limits imposed by Shannon's theorem with much less decoding complexity than the Viterbi algorithm on the long convolutional codes that would be required for the same performance makes giving the way to turbo codes to be replaced. By using Mathlab software to develop software programming which gave the suitable and accurate simulation. In fact, simulink, profiler, and guide are in one function.

Program development takes place across this simulation. This give short time and speeding in the software development.

Upon this project also, we can discover a lot of benefits by using this turbo codes based on space time frequency with QPSK modulation technique to our country development. We can increase of the subscribers by use this technique. High data of transmission can be increase by reducing a number of bit errors. As providers, by having a small bandwidth output of signalling, the cost of install this transmission will be reduces. From the result and analysis that had been made, it clearly stated from the resulted simulation, bit error rate performance will reduce perpendicular with the expanding of the Eb/No, and by this explanation the bit error will trim down and get a maximum diversity order for the system. They also can provide a large data transmission. It showed that, we will improve the capacity channel and the efficiency of the delivering the data through the wireless network the level of speediness also can be increased by using this method and will attempt the project objectives.

7.0 FUTURE AND DEVELOPMENTS

In the future, this project can be improved to become a commercial technology. This improvement will radically improve the coding technique in space time coding, while at the same time increasing the use of the benefits of using this method. It is expected that this features will significantly increase the use of WiMAX and ASTRO in our country. The cost of the installation nowadays invested by the giant company will be able to afford by personal user who are willing to do so.

In the next few year may be the turbo codes will catering to the need of very low power transmission with of the high data transmission. Turbo code will be used widely and extensively in 4G and above mobile telephony standards. It is also can increase of usage in mediaFLO, terrestrial mobile television from Qualcomm. Furthermore, NASA mission will adapt more information from the turbo code application as an alternative to RS-Viterbi codes. Just now they are still implemented this codes in Mars Reconnaissance Orbiter. As my high expectation on this turbo codes implementation, it will be a great usage in wireless metropolitan network standard in future.

The fundamental concept can be strengthened through some research that can be done such as these projects:

1) Using higher M-ary PSK or other modulation such as QAM or DQPSK. These techniques are more useful in mobile communication.

2) Using other method to create a better result such as add power density function (PDF), and Raleigh Fading.

3) Use other type of software such as Maple, Mathcad to simulate the BER performance.

4) Implementation of hardware for the simulation

7.0 REFERENCES

[1] S.Benedetto, D.Divsalar, G.Montorsi and F.Pollara, "Serial concatenasion of interleaved codes: Performance analysis, design and iterative decoding," IEEE Trans. Inform. Theory, vol 44,pp. 909-929, May 1998.

[2] C.Douillard M Jezequel, C Berrou, A.Picart, P Didier and A Glaivieux, " Iterative correction of Intersysmbol interference Turboqualization," European Trans. Telecommun, Vol 6, pp. 507-511, Sept. 1995

[3] C. Berrou, A. Glavieux, and P. Thitimajshima, "Near Shannon limit error-correcting coding: Turbo codes," in Proceedings of ICC'93, (Geneva, Switzerland), pp. 1064-1070, May 1980. G. Caire, G. Taricco, and E. Biglieri, "Bitinterleaved

[4] Website: http://wikipedia.org/wiki/modulation

[5] Alister burr, Modulation and Coding for Wireles communication, Prentice Hall, 2001

[6] Abdelwahab Kharab and Ronald B. Guenther, An introduction to numerical method- A Matlab Approach, Chapman & Hall/CRC, 2002.

[7] Website: http://wikipedia.org/wiki/modulation

[8] I. E. Telatar, "Capacity of multi-antenna Gaussian channels," Eur. Trans. Telecommun., vol. 10, no. 6, pp. 585–595, Nov99

[9] G. J. Foschini and M. J. Gans, "On limits of wireless Communications in a fading environment when using Multiple antennas," Wireless Pers. Commun., vol. 6, pp. 311–335, Mar. 1998.

[10] V. Tarokh, N. Seshadri, and A. R. Calderbank, "Space-time codes for high data rate wireless communication: Performance riterion and code construction," IEEE Trans. Inform. Theory, vol. 44, pp. 744–765, Mar. 1998.

[11] M. P. Fitz, J. Grimm, and S. Siwamogsatham, "A new view of performance analysis techniques in correlated Rayleigh fading," presented at the IEEE Wireless Communications and Networking Conf., New Orleans,

[12] S. Benedetto and G. Montorsi, "Unveiling turbo codes: Some results on parallel concatenated coding schemes," IEEE Inform. Theory, vol. 42, pp. 409–428, Mar. 1996.

[13] L. C. Perez, J. Seghers, and D. J. Costello Jr., "A distance spectrum interpretation of turbo codes," IEEE Inform. Theory, vol. 42, pp. 1698–1709, Nov. 1996. LA, Sept. 1999.

[14] T. A. Chen, M. P. Fitz, W. Y. Kuo, M. D. Zoltowski, and J. H. Grimm, "A space-time model for frequency nonselective Rayleigh fading channels

[15] Bernand Sklar, Digital Communication Fundamental and Application, 2nd Edition pp437- 460