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Analysis of Single RF Performance on MIMO-OFDM System Using Turbo Code and V-BLAST MMSE Detection

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***Abstract*—Along with the passing time and recent technology, the advancement of information technology has been increased in the wireless technology. The common methods that are used in this wireless communication are MIMO (*Multiple Input Multiple Output*) and OFDM (*Orthogonal Frequency Division Multiplexing*). MIMO is a system stands for a couple antenna on the transmitter and receiver which are working on the*multipath* component. While OFDM (*Orthogonal Frequency Division Multiplexing*) is a transmission method using *multicarrier* technique, dividing *spectrum* frequency into a couple *subcarrier*. The combination of MIMO and OFDM results in a high-speed transfer data system. The *Single* RF has reduced the usage of *RF Front-End* into a bigger matrix size in the conventional MIMO system. This final project will discuss about the Single RF system of MIMO-OFDM with the V-BLAST (Vertical Bell Laboratories Space-Time) and MMSE (*Minimum Mean Square Error*) detectionwhich is used to remove ISI (*Intersymbol Interference*) combined with the*Turbo Code*,where the*Turbo Encoder* that lies on the transmitter side is also the*Turbo Decoder* in the receiver side. MIMO-OFDM utilizesthe *Single* RF (Radio Frequency) basis. The test on this final project will include a Single RF antenna on the MIMO-OFDM system, MIMO-OFDM with the V-BLAST detector and MMSE MIMO-OFDM with the Turbo Code, by using 64 QAM modulation. The expected result is the analysis performance of the Single RF on the MIMO-OFDM system using Turbo Code and V-BLAST MMSEDetection. The system will be shown on the*Bit Error Rate* (BER) toward the Signal to Noise Ratio (SNR).**

***Index Terms*—MIMO, OFDM, V-BLAST, MMSE, SingleRF, Turbo Code, BER, SNR.**

I. INTRODUCTION

Wireless communication technology has been increased significantly in the past few years and will be the most important role in our life. The demand on this wireless communication has exponentially increased, such as the connectivity needs, the various services, and the better quality. This development is able to help the network communication to work efficiently, easily, quickly, and cheaply. The common techniques that are used for the wireless system are MIMO (Multiple Input Multiple Output) and OFDM (Orthogonal Division Multiplexing). MIMO is a system of a couple of antenna in the *transmitter* and *receiver* that works properly in the multipath component. Meanwhile, OFDM (*Orthogonal Frequency Division Multiplexing*) is a transmission method that utilizes the *multicarrier*technique which divides frequency *spectrum* into a couple of *subcarrier*[1].To minimize the necessity of the big matrix size, a *Single* RF (*Radio Frequency*) used lies on the receiver side, *single* RF function [8]. In this paper, we will discuss about how the single RF technique on the MIMO-OFDM system with V-BLAST (Vertical Bell Laboratories space-time) and MMSE (Minimum Mean Square Error) detection is used to remove ISI (Intersymbol Interference). It is equipped with the *Turbo Code* MIMO-OFDM that utilizes a *single* RF (*Radio Frequency*), or usually called as front-end RF which functions to get more energy efficiency, also the 2x2 antenna *Single* RF as its data communication medium with WLAN 802.11n standard. The results of this system can be seen on BER curve toward SNR.

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II. SINGLE-RF ANTENNA IN MIMO-OFDM SYSTEM

A. Multiple-Input Multiple-Output (MIMO)

In a wireless communication system, the signal transmission will be the ravages of fading, so the system will decline in performance. The demands ofthe increased data rates and thewireless service communications system quality generate the emergence of a new technique to improve the channel.This can be achieved by using multi antenna as well as the better transmitter and receiver, as shown in Figure 1.This system is known as the Multiple Input Multiple Output (MIMO).

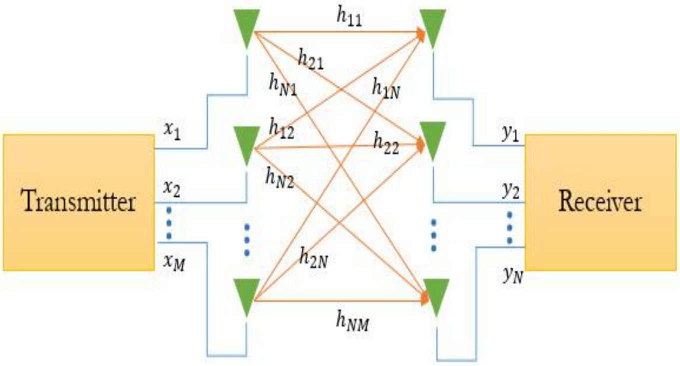

Fig. 1 Conventional MIMO Scheme.

The antenna receiver will receive the signals from the antenna transmitter that is multiplied by a matrix channel. In general, the received signal by the antenna receiver which is multiplied by the channel (h) can be formulated as in the equation

$$\begin{bmatrix} y1 \\ y2 \\ \vdots \\ y_m \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1N} \\ h_{21} & h_{22} & \cdots & h_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ h_{m1} & h_{m2} & \cdots & h_{MN} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_N \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_M \end{bmatrix} \quad (1)$$

According to (1), the matrix above can be expressed in the Equation (2).

$$y = Hx + n \quad (2)$$

where H is channel matrix, x is symbol transmitted and n is noise

B. QAM Modulation

QAM is the combination of ASK and PSK, i.e., a form of digital modulation where the digital information consists of amplitude and phase signal carrier. QAM is utilized to combine two signal modulation amplitude in a single channel, thus the bandwidth can be effective. QAM is used with the pulse amplitude modulation (PAM) in the digital system, especially in the wireless application. QAM conveys the data by changing the two amplitude waves.

$$S_i(t) = r_i \cos(w_c t + \theta_i) \\ = r_i cos\omega_c tcos\theta_i - r_i sin\omega_c tsin\theta_i \quad (3)$$

By combining the amplitude and phase angle $r_i\theta_i$, each sample of the output signal is given by

$$S(t) = x(t)p_i \cos \omega ct - y(t)q_i \sin \omega ct \quad (4)$$

C. OFDM Receiver based on Single-RF

MIMO is a technique that can increase the bit rate without expanding bandwidth. It is known that the antenna with MIMO systems have the greater channel capacity than the antenna with SISO (Single-Input Single-Output). In [2] the single RF technique is introduced to reduce the amount of RF front-end in the MIMO. This technique is a modification to minimize the number of RF front-end signal processing of MIMO system in which the radio frequency (RF) can be done with an RF signal processing. It is based on the ESPAR (Electrically Parasitic Antenna Radiator)antenna, as illustrated in Figure 2.

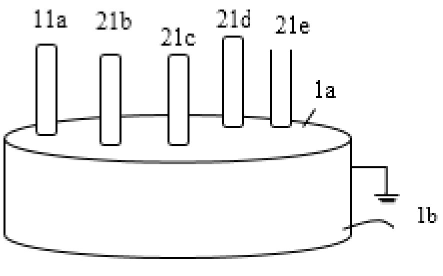

Fig. 2 ESPAR Antenna on OFDM System Receiver

In Figure 2, it can be seen that the ESPAR antenna is composed by a radiator element and one or more parasitic elements, which is terminated with a variable capacitor. The directivity of ESPAR antenna is set by the variable capacitor. Because the radiator element and parasitic element arethe couple that generate electromagnetic waves, the output of ESPAR antenna is the cost of the received signal on each antenna element. It can be expressed as in Equation (5).

$$v(t) = a.v_{d\ (t)} + \beta e^{\frac{j2\pi t}{Ts}} v_{p\ (t)} \quad (5)$$

α and β are the constants. In the signal processing, α andβ are the channel impulse response of (h) whose coefficient of matrix element is distorted. The received signal in parasitic element $((t))$ has a phase shift, because there is a variable capacitor that controls the antenna directivity. Thus, the signal received by the parasitic element is multiplied with $e^{j2\pi tTs}$, in which Ts is a FFT period of OFDM signal.

D. Transmission Channel

In the transmission channel, the signal transmitted through wireless channel will be reflected on various objects (buildings, trees, etc.) in the various paths before arriving at the receiver,thus the signal can be weak. It is called multipath fading. The effect of multipath fading generates a fluctuation in the amplitude and phase of the signal.

In this paper, Rayleigh channel is created by 2-taps where the signals sent from the transmitter to the receiver will have two conditions. The first condition is LOS (Line of Sight) that is no obstructions between the transmitter and the receiver. The second condition is that the signal is delayed by the obstructions

E. V-BLAST Detector

The capacity increases in the linear quantities along with the antenna transmitter, as long as the antenna receiver is more or equal to the number of the antenna transmitter. To obtainthis capacity, a diagonal blast is set by Foscini. The scheme uses the array multi-element antenna upon two sides wireless network. However, the complexity of the d-blast leads to the V-BLAST, that is the modification of blast. Two mulings, namely Zero Forcing (ZF) and Minimum Mean Squared Error (MMSE), areinitially used as the algorithms detection, the scheme detection blast based on the successive interference cancellation. The parallel interference cancellation scheme is also shown in Figure 3.

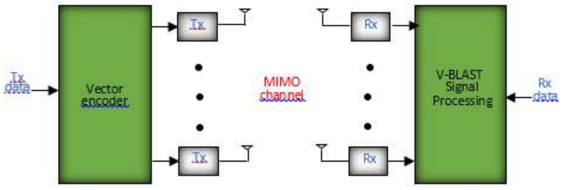

Fig. 3 V-BLAST Detector.

H denotes the channel matrix dimension of $n_r.n_T$ where element $h_{i.j}$ expresses the coefficient of fading complex for the path from the transmitter j to the antenna transmitter$i$. This fading coefficient is modeled by a complex random variable of the main Gaussian zero complex, which is the variance of 0,5 for each dimension. A represents the symbol vector which represents the vector symbol transmitted with the n_T dimension. I,n denotes the complex vector of simple independent AWGN received through each antenna and zero mean and noise variant σ_n^2.

F.CHANNEL ESTIMATION

After the channel impulse response can be derived, the next step is estimating the pilot symbol P_1 and P_2 which are sent from the first and second transmitters respectively. In Equation (6), the received pilot symbol in the i-thesingle-RF antenna (i =1 and 2) in frequency domain is given by

$$P_i = [P_{i,0}, P_{i,1,\cdots,} P_{i,N-1}]T \qquad (6)$$

where$P_{i,N}$ is the pilot symbol in the N-th (56-th) sub-carrierand in the i-thsingle-RFantenna($i = 1$ and 2). The received signal in the i-thsingle-RF antenna is given by

$$ui = (h_{i,1ns} + Gh_{i,1s})P_2 + (h_{i,2ns} + Gh_{i,2s})P_2 + z = (P_1 h_{i,1ns} + GP_1 h_{i,1s}) + (P_2 h_{i,2ns} + GP_2 h_{i,2s}) + z \qquad (7)$$

where: u_i is the received signal in the i-th Rx ($i = 1$ and 2)$h_{i,1}{}^{ns}$ is the channel response between Tx-1 and $i - th$ Rx (*non-shifting element*), $h_{i,2}{}^{ns}$ is the channel response between Tx-2 and $i - th$ Rx (*non-shifting element*) , $h_{i,1}{}^{s}$ is the channel response between Tx-1 and $i - th$ Rx (*shifting element*), $h_{i,2}{}^{s}$ is the channel response between Tx-2 and $i - th$ Rx (*shifting element*), $P_{1,2}$ is the pilot symbol sent on Tx-1 and Tx-2, G is the ICI in the frequency domain and zis the noise AWGN.

The value of auto-correlation (R) can be derived in Equation(8)

$$R = (P_1 R_h P_1 H + GP_1 R_h P_{2^H} G_H) + (P_2 R_h P_{2^H} + GP_2 R_h P_{2^H} G_H) + \sigma_{z^2} I \qquad (8)$$

and cross-correlation(B)is given by Equation (9) and (10).

$$B_{i^{ns}} = P_i R_h \qquad (9)$$
$$B_{i^s} = GP_i R_h \qquad (10)$$

where$i$ = 1 and 2, then $B_i{}^{ns}$ and $B_i{}^{s}$ are cross-correlation matrix for the non-shifting elementand shifting elements,respectively. To find the approximate value, weighting (W) is required. It is the multiply between matrix invers of auto-correlation(R) and matrix of cross-correlation(B). It can be derived by

$$W_{i^{ns}} = R^{-1} B_{i^{ns}} \qquad (11)$$
$$W_{i^s} = R^{-1} B_{i^s} \qquad (12)$$

From the weighting value (W), we can compute the channel response value in each receiver element.

G.*Turbo Code*

1. *Turbo Encoder*

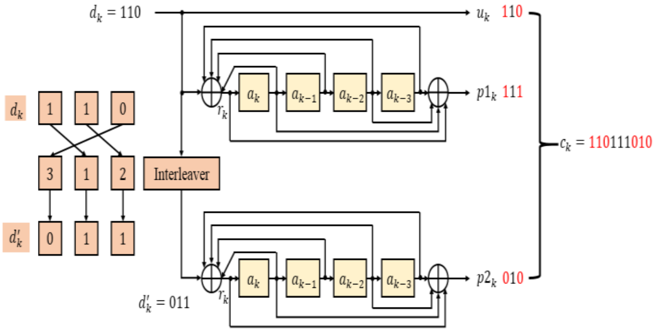

Fig. 4 Turbo Encoder (1,33/37)Rate 1/3.

From Figure 4, first, the bits of data are copied to the first and second RSC encoder. The first copy will produce a systematic output. Then, the bits of data are encrypted with a block interleaver. Each RSC encoder generates the error-correction bits that are the parity bits. The original data bits and the parity bits of the second RSC encoder output are multiplexed into a block called code word.

2. *Turbo Decoder*

The decoding process is the inverse of the encoding process in which the block utilizes SOVA (Soft Output Viterbi Algorithm) as the forward error correction using trellis diagram.

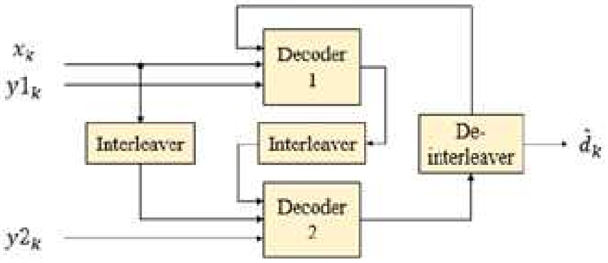

Fig. 5 Turbo Decoder Rate 1/3.

III. MIMO-OFDM BASED ON SINGLE-RF WITH CODING

A. Simulation Parameter

Table 1 SIMULATION PAREMETER

Component	Parameter	Value
Transmitter	Antenna	2
	Pilot Sequence	HTLTF
	Pilot Structure	Block Type
	Encoder	Turbo Code
	Generator Polynomial	(1,33/37)
	Code rate	1/3
	Modulator	64-QAM
	Sub-carrier	56
	IFFT size	64
	Guard Interval Length	25% of IFFT size
Channel	Rayleigh Fading AWGN	2 -tap
	Antenna Size	64
Receiver	Channel estimation	MMSE
	Detector	V-BLAST-MMSE
	Demodulator	64-QAM
	Decoder	SOVA

B. System Model

1. Transmitter

The transmitter block diagram of MIMO-OFDM system is conducted with the digital data signals which will then be divided into two, which one part is the cyclic shift to give a delay. The data input will then be modulated using QAM,the data input of the serial is later changed into the form of the parallel to block the parallel between the sub carrier,which is a pilot data for the IFFT process that serves to form the OFDM symbols and change the time domain into the frequencydomain.Next, the OFDM symbol is inserted into the CP (cyclic prefix) that serves to prevent the interference (intersymbol interference) process, then the data transmission of MIMO utilizes the system.

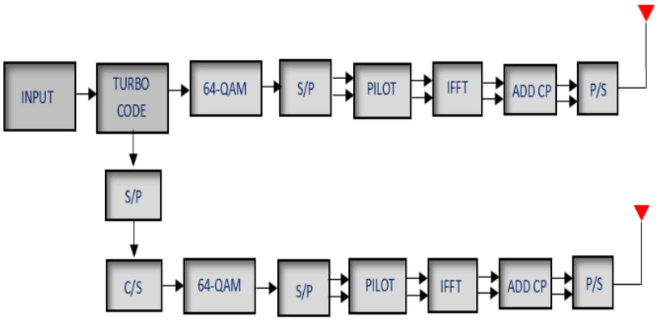

Fig. 6 Block Diagram of MIMO-OFDM System Transmitter.

2. Receiver

On the receiver, the OFDM symbol sent will be received by the Single RF ESPAR antenna, a serial data that will be converted into a parallel in the serial block to the next parallel CP (Cyclic Prefix) removal and the FFT Process which can be used to release ISI that is carried from the signal source. The symbols that still contain the data pilot islater processed in the Chanel Estimation, after the estimated channel response data that do not contain pilot enter the block detector. The result of this detector will be converted to the serial form in parallel to the serial block, after that QAM goes to the modulation again. The next step is the detecting step for math process SNR and BER to figure out a bit of error that happens so we can understand what is good or bad for the processed signal, thus we can determine the result of the system.

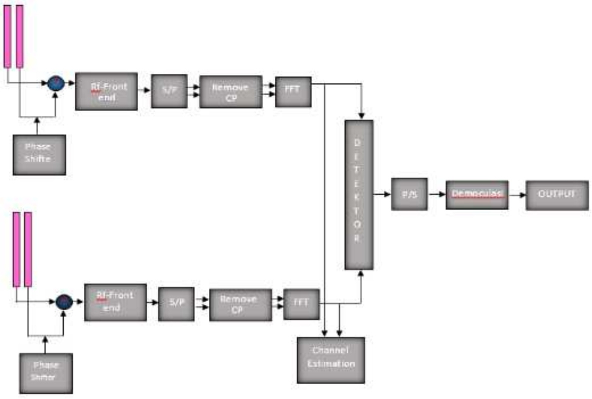

Fig. 7 Block Diagram of MIMO-OFDM System Receiver Based on Single-RF.

IV. SIMULATION AND DISCUSSION

A. Channel Estimation Assessment

1. Magnitude and Phase Curve in the Radiator Element

The received signal on the beneficiaries is distorted, this is caused by the variation of channel response, if the received signal is directly detected by the detector, there will be a mistake.It takes the estimation channel to know the channel condition. The channel uses the 2-taps Rayleighin the simulation to be taken into the channels on h12.The observations on the magnitude and phase curve for the process are conducted.The Figure 8 below shows the observation of the phase curve. The curve in the figure shows that the theory and the estimated values are close to each other or almost similar, which indicates that the channel estimation works well.

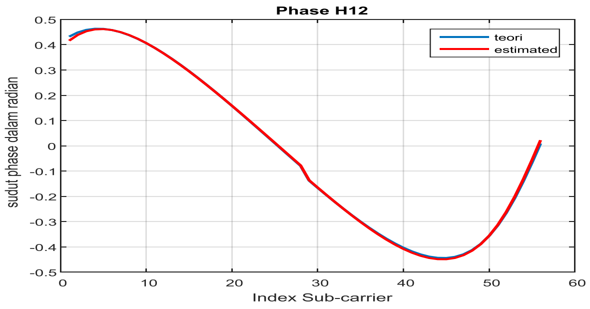

Fig. 8 Frequency Response (Phase H12)

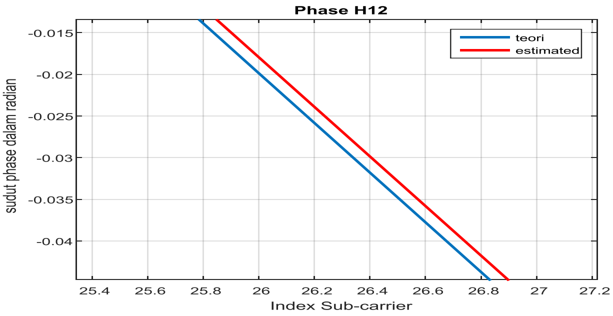

Fig. 9 Frequency Response (Phase H12)

If it is zoomed to clarify the display, the curve will look different between the theory and estimation, yet the gap is not too striking. On the observation result, it is obtained that the index sub carrier becomes 26, and the estimation magnitude generates signal of -0.0179 dB with the phase of 2.8293 rad. The theory channel generates the magnitude signal value of -0.0199 db in the phase of 2.8852 rad. The next is the observation of the curve magnitude. Our observations on the curve magnitude works well.

B. MIMO-OFDM Detector Performance Based on Single-RF

MIMO-OFDM uses the turbo code and two antennas (the transmitter and the receiver) for the single-rf. There are two kinds of detector used, the V-BLAST (Vertical Synchronization Bell Laboratories Space Time) and MMSE (Minimum Mean Square Error). The comparison of the detector can be seen from their performance and the bit of data which is randomly increase, in the performance test of 224 bit. The channels used in testing the performance of the detector are AWGN and Rayleigh fading. In this system, the large guard intervals used are IFFT and FFT, and the subcarrier is about 56 with the modulation of 64 QAM. Figure 10 shows the performance of the system, the direct observation is conducted to the standard communication in general, i.e., 10^{-3}. In the MMSE detector system, it has not reached the agreed result of the SNR value of 35 dB. There is still high error found in the MMSE detector system. The systems use V-BLAST detector value.

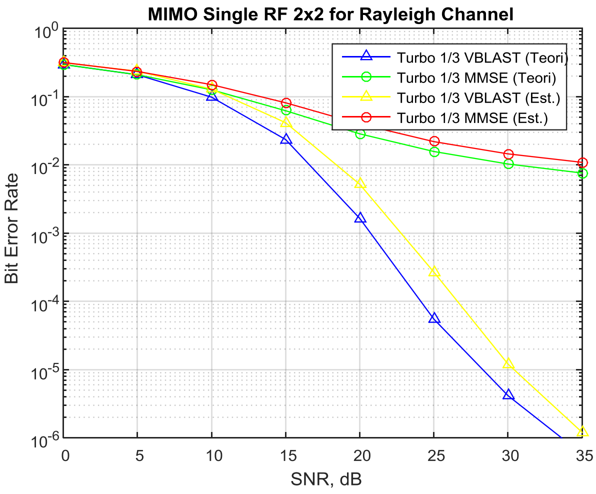

Fig. 10 Detector Performance in MIMO-OFDM System Based on Single-RF.

C. MIMO-OFDM Turbo Code Performance Based on Single-RF

The MIMO-OFM system performance analysis uses the antenna of single RF and the coding turbo code rate of $\frac{1}{3}$, this chapter analyzes the performance of code turbo with the rate system of $\frac{1}{3}$ based on the MIMO-OFDM single RF in comparison with the performance system without using the coding turbo. The test and observation are also conducted for the two channels. The performance system which utilizes the coding shows its performance, the theory channel obtains the SNR value of 20.72 dB and the estimation condition obtains the SNR value of 22.75 dB. On the system without coding, it obtains the SNR value of 21.77dB for the theory channel and 23.8 dB for the estimation. If they are compared, it can be observed that the system with the coding turbo is better than the performance without the coding system.

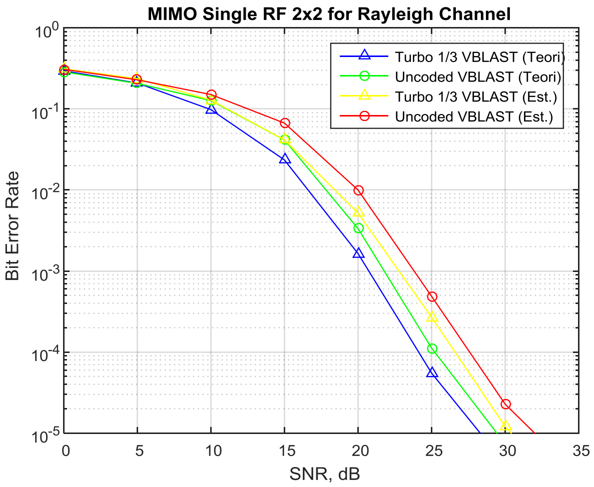

Fig.11 Turbo Code 1/3 Performance in MIMO-OFDM System Based on Single-RF

D. Comparison between Single-RF and Conventional Antenna

On the configuration of MIMO-OFDM detector system which uses V-BLAST detector and the turbo code rate of $\frac{1}{3}$, the antennas of the single RF system really work better than the 2x2 configuration theoretically and conventionally estimated. However, the conventional 2x4 configuration shows better performance than the single RF configuration. From the comparison between the theory and estimation toward the single RF antenna, it is obtained that the SNR values for the theory channel is 22.75 dB and 20.72 db for the estimation channel. For the 2x2 antenna, the SNR value for the theory channel is 27.5 dB and for the estimation channel is 33.5 dB. For the 2x4 antenna, the SNR value for the theory channel is 13.3 dB and for the estimation channel is 14.35 dB

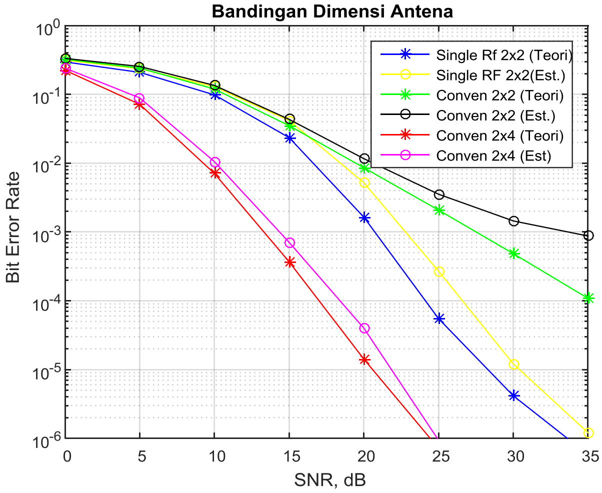

Fig.11 Antenna Comparison in MIMO-OFDM System Using Turbo Code

V.CONCLUSION

From the discussion of the performance system based on MIMO-OFDM Single RF using Turbo code and V-BLAST and MMSE Detection, it can be concluded that the technique estimation works well. It is marked with the coincidence of the estimation and theory curve figure. The performance of V-BLAST detector is conducted. The most reliable SNR configuration on BER 10^{-3}can generate the SNR value of 22,75 dB for the theory or the perfect channel, and 20,72 dB to the estimation channel. The comparison of MIMO-OFDM antenna system configuration is also conducted. The single RF can work better than the conventional in 2 configuration 2x2, yet it still cannot go beyond the performance of the conventional antenna in configuration 2x4. The comparison of the system which uses the coding turboshow their performance. The theory channel obtains the SNR value of 20.72 dB, while the estimation condition obtains the SNR value of 22.7dB.

REFERENCES

[1] AntonisKalis, Athanasios G. Kanatas, Constantinos B. Papadias, ”A Novel Approach to MIMO Transmission Using a Single RF Front-End”, IEEE Journal on Selected Areas in Communications vol. 26 no. 6, Agustus 2008.

[2] Diego Javier ReinosoChisaguanodan Minoru Okada, ”MIMO-OFDM Receiver Using a Modified ESPAR Antena with Periodically Changed Directivity”, 13th International Symposium on Communications and Information Technologies (ISCIT), IEEE Press, 2013.

[3] I Gede Puja Astawadan Minoru Okada, “An RF Signal Processing based Diversity Scheme for MIMO-OFDM Systems”, IEICE Trans. Fundamentals, vol. E95-A, no. 2, 2012 p.p. 515–524.

[4] I Gede Puja Astawa, YoedyMoegiharto, Hendy Briantoro, Ahmad Zainudin, NovitaAstin, Minoru Okada, ”ESPAR Antenna Based Diversity Scheme for Multiple Antenna OFDM System”, IES (International Electronics Symposim), 2015.

[5] M. M. Kamruzzaman, “Performance of Turbo Coded Wireless Link for SISO-OFDM, SIMO-OFDM, MISO-OFDM and MIMO-OFDM System”, Proceedings of 14th International Conference on Computer and Information Technology (ICCIT 2011) 22-24 December, 2011, Dhaka, Bangladesh, IEEE Press, 2011.

[6] Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung-GuKang, *MIMO-OFDM Wireless Communications with MATLAB*, IEEE Press, 2010.

[7] K. DeerghaRao, *Channel Coding Techniques for Wireless Communication*. Springer. 2015.

[8] J. Castineira M., Patrick Guy F., *Essentials of Error-Control Coding.* John Wiley & Sons, Ltd. 2006.

[9] ChangyoungAn and Heung-GyoonRyu, MIMO Receiver System Using Single RF Front-End, International Conference on Signal Processing and Integrated Networks (SPIN), IEEE Press, 2014.

[10] Astawa, I.G.P., Moegiharto, Y., Zainudin, A., Salim, I.D.A.,Anggraeni,N.A.”Performance of MIMO-OFDM using convolution codes with QAM modulation”, Proc. SPIE 9159, Sixth International Conference on Digital Image Processing (ICDIP), 2014

[11] Morelos, Robert H. And Zaragoza, *The Art of Error Correcting Coding*. John Wiley & Sons, Ltd. 2006