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WORKING ANALYSIS OF SPACE TIME TRELLIS CODE ON WIFI MIMO (2X2) SYSTEM OFDM

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ABSTRACT

Wireless communication nowadays requires the provision of a system with reliable performance, efficient use of bandwidth, efficient power, and better coverage because it is in line with human needs for applications that require high and fast data rates. One of the concepts and methods to meet these needs is using an antenna technique with many transmitters and receivers or often called Multiple Input Multiple Output (MIMO) by adding a strategy at the time of delivery, namely the Space-Time Coding (STC) technique. In addition, the application of Orthogonal Frequency Division Multiplexing (OFDM) on MIMO-STC will more efficiently use bandwidth. The Space-Time Trellis Code (STTC) method is one of the techniques of diversity in sending data with complex coding so that coding reinforcement is achieved and is applied to the OFDM MIMO system so that it is hoped that the achievement of a system with reliable performance can be achieved. The simulation that is carried out presents the STTC and OFDM schemes on multi antennas (2 transmitters x 2 receivers) with a Combiner and Maximum Likelihood Sequence Estimator (MLSE) detection algorithm on the receiver to get the quality of the sending signal in the performance analysis of Bit Error Rate (BER) with Signal to Noise Ratio (SNR). The simulation results are shown by modulation with M-array Phase Shift Keying (MPSK) and the number of symbols sent by giving different input parameter values. The results show that the use of the number of carriers and the size of the Fast Fourier Transform (FFT) is large and the modulation type with a small constellation produces a low BER and throughput at high SNR.

Keywords: *MiMo, STC, STTC, OFDM, BER, SNR*

INTRODUCTION

Wireless communication currently demands the provision of a system with reliable performance, efficient use of bandwidth, efficient power, and better coverage because it is in line with human needs for applications that require high data rates. One of the obstacles in the wireless communication system is the received power fading phenomenon. Fading occurs due to the effect of a multipath signal where the signal travels in different paths and undergoes reflection, scattering, and attenuation resulting in changes in the amplitude and phase of each signal.

One technique that is widely used to overcome the multipath effect is the application of the Multiple Input Multiple Output (MIMO) technique on the antenna because the reflected signal that occurs during transmission strengthens the main signal [11]. Along wisth the development of technology, this system is combined with the Orthogonal Frequency Division Multiplexing (OFDM) system where this OFDM system can save bandwidth and handle selective fading channel effects that occur in a high-speed data transmission system. The combination of these two systems is often called the MIMO-OFDM system which is currently the focus of research for future telecommunications developments.

MIMO is the use of multiple antennas both at the sender and at the receiver at the same frequency and at the same time [1]. Multi antennas on the sender can be done in two ways, namely using Spatial Multiplexing or Space-Time Coding (STC) [2]. In STC the information is encoded on the transmit antenna through the dimensions of space (antenna) and time (symbol) while in spatial multiplexing, information is not encoded so that the STC technique is considered to be better in terms of quality and safety [2].

Space-Time Coding can be categorized into two types, namely Space-Time Block Codes (STBC) and Space-Time Trellis Coding (STTC). STBC transmits symbols using orthogonal block structures so that the decoding process becomes simpler, but only provides diversity gain. Meanwhile, STTC utilizes the convolutional principle. STTC not only provides diversity gain but also coding gain because the code sent is more complex and there is a maximum likelihood algorithm process that is implemented through the viterbi detection algorithm so that the process becomes more complex on the sender and receiver sides. This complex process proves that STTC's performance is better than STBC based on the natural Alamouti technique [3][8]. Therefore, this research analyzes the performance of the Space-Time Trellis Code (STTC) on the MIMO OFDM channel on the quality of the received signal, in this case, the parameters used are Bit Error Rate (BER) vs. SNR and Throughput.

METHOD

Additive White Gaussian Noise (AWGN) Channel

The AWGN channel is an ideal channel that only has Additive White Gaussian Noise (AWGN) noise in it. The ideal channel means that this channel does not experience distortion (signal changes) in the signal to be sent, meaning that the ideal channel has unlimited bandwidth and the frequency response is fixed for all frequencies [4].

The modeling of the AWGN channel is shown in FIGURE 1[4]:

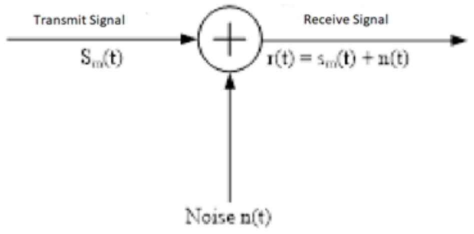

FIGURE 1. AWGN channel modeling

Where :

$\boldsymbol{s_m(t)}$= information signal sent

$\boldsymbol{n(t)}$ = *noise*

$\boldsymbol{r(t)}$ = receive signal

It is defined that the information signal $s_m(t)$ is transmitted at 0 ≤ t ≤ T intervals, then the received signal after distorted noise is:

$$r(t) = s_m(t) + n(t), 0 \leq t \leq T \quad (2.1)$$

Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is a technology patented in 1970 [6] by dividing high-speed serial data into a series of parallel bits with lower bit rates. These bits will be carried by orthogonal subcarriers where one subcarrier with another subcarrier overlaps but does not cause interference effects. Each subcarrier has a low bit rate, this will reduce the effect of Inter Symbol Interference (ISI). The following is a comparison of the frequency spectrum (bandwidth utilization) of conventional FDM and OFDM multi carriers [7].

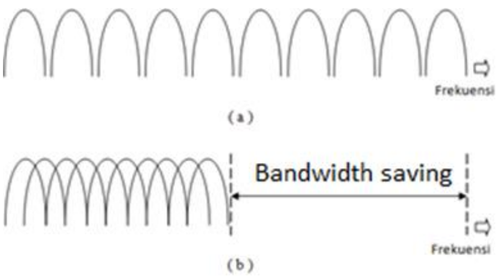

FIGURE 2. Conventional FDM Modulation Technique (a), OFDM Modulation Technique (b)

This OFDM system uses a modern Digital Signal Processing (DSP) technique, namely Discrete Fourier Transform (DFT). This technique will reduce the complexity of the modulator system on the transmitter and demodulator systems on the receiver which is generally formed from oscillators, mixers, and filters. For modulation using Inverse Fast Fourier Transform (IFFT), while for demodulation using Fast Fourier Transform (FFT).

Space-Time Coding (STC)

The information signal capacity of a wireless communication system can be dramatically increased by using several antennas (MIMO), but the basic problem with a MIMO system is the mapping operation at the transmitter and the inversion adjustment at the receiver. To optimize system performance, it is hoped that MIMO can overcome multipath problems by using several transmission methods. One effective approach is to use coding techniques on several transmitting antennas that can describe and correct for the signal to be transmitted. This is intended so that the initial signal sent can be maintained when it is received. This is what is referred to as Space-Time Coding[9] because it defines coding that operates through space (antenna) and time (symbol). Separate coding using multiple antennas at a certain period with several symbols at regular intervals. Because in general the encoding only operates across the time domain by using many symbols [9].

Space-Time Coding is a combination of modulation techniques, channel coding techniques, and antenna diversity [9]. In Space-Time Coding, the signal processing at the transmitter is not carried out only in the time domain but also in the space domain so that the processed and encoded signal is sent through the sending antenna and then to introduce the correlation between other signals sent from other antennas at the same period. different. This is done because the data rate and performance can be significantly improved without sacrificing bandwidth [9].

The idea of Space-Time Coding was first pioneered by Tarokh, Seshadri, and Calderbank[13]. They prove that diversity and coding techniques can be obtained simultaneously by utilizing Space-Time Coding because it is a method that provides diversity on a multipath channel using multiple antennas to obtain maximum diversity on the channel. Meanwhile, multipath fading in multi-antenna systems is generally influenced by time diversity, frequency diversity, and space diversity.

MIMO-Space Time Trellis Coding (STTC)

The Space-Time Trellis Code (STTC) was first introduced by Tarokh, Seshandari, and Calderbank[13]. STTC is a MIMO technique that provides full diversity and coding gain [13]. Here is a block diagram of STTC with M transmit antennas and N receive antennas.

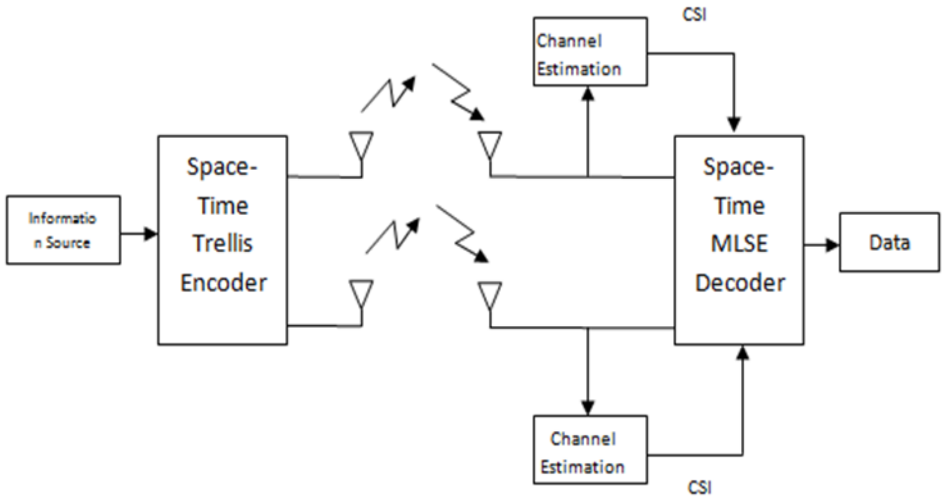

FIGURE 3. Block Diagram STTC[14]

STTC DESIGN ON MIMO SYSTEM

STTC scheme on MIMO System

FIGURE 4 shows a 2 X 2 STTC scheme, where the scheme consists of a 2-antenna transmitter and a 2-antenna receiver (MIMO).

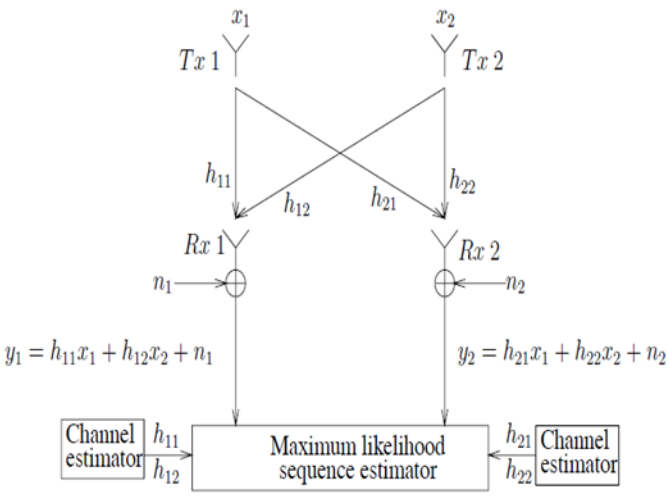

FIGURE 4. 2 X 2 STTC Scheme [16] [8]

In FIGURE 4. there are x1 and x2 which are symbols transmitted by the Tx1 and Tx2 antennas. At the receiving end of Rx1 and Rx2, the equation [16] is obtained:

$$y_1 = h_{11}x_1 + h_{12}x_2 + n_1 \tag{2.2}$$

$$y_2 = h_{21}x_1 + h_{22}x_2 + n_2 \tag{2.3}$$

Where h11, h12, h21, and h22 are the estimated channel coefficients on the channel block estimator and n1, n2 are complex random variables representing thermal interference and noise. The STTC decoder uses a Viterbial algorithm based on the Maximum Likelihood Sequence Estimator (MLSE) to trace its trellis code [18].

Block Diagram STTC on MIMO System

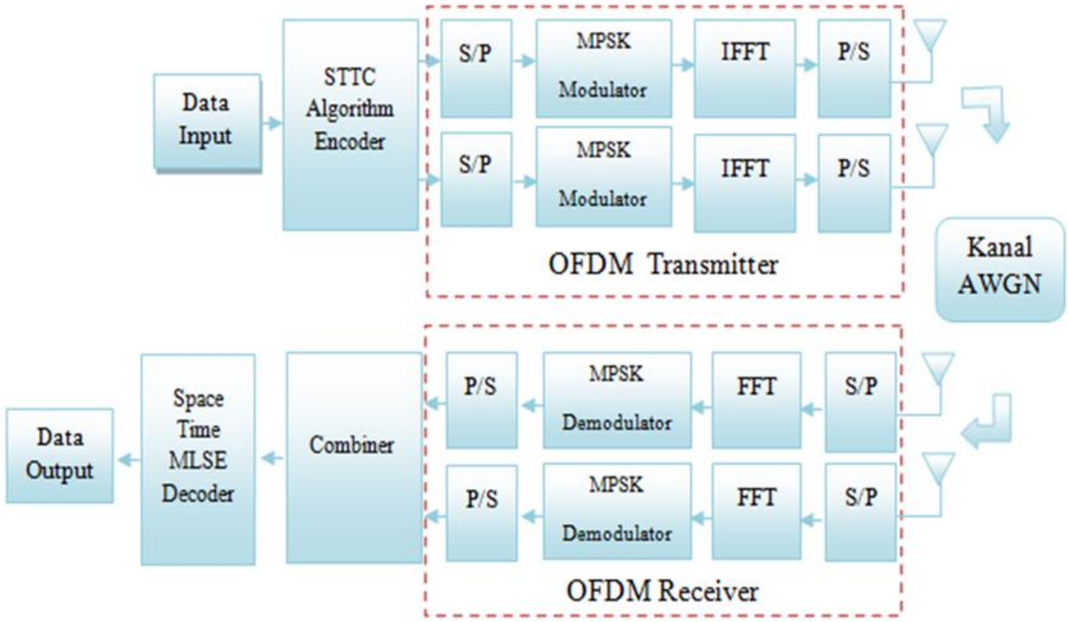

FIGURE 5. Block Diagram of **STTC**

Input Data

The input data is a signal in the form of random binary bits. In this input signal, the A/D (Analog to Digital) Converter process occurs where each bit formed will be sent to each Transmitter (Tx) and then transmitted to the Receiver (Rx), with the transmission flow in the block diagram above.

STTC Algorithm Encoder

In this block, the binary bits of the input data are coded into trellis code. For bit coding, a trellis diagram is needed which functions to map random data '0' and '1' into codewords. The output of this trellis diagram consists of two symbols which will then be passed to the serial to parallel block.

Serial to Parallel (S/P)

Serves to convert serial data into parallel. Where the number of N-parallel is the number of data inputs, and then it will be modulated with the QPSK modulator into OFDM subcarriers. In the simulation program the process of changing serial data into parallel.

MPSK Modulator

After the S/P results, each data bit will be modulated with the MPSK modulation technique. In this block, the input is modulated into MPSK symbols where 1 symbol carries 2n bits of data.

Inverse Fast Fourier Transform (IFFT)

The Inverse Fast Fourier Transform (IFFT) block in the OFDM system functions to generate carrier frequencies that are orthogonal to one another. The number of IFFT points in the implementation is 2n, where n is a positive integer. The IFFT point can be set according to the number of subcarriers used or greater than the number of subcarriers.

Paralel To Serial (P/S)

This block converts the parallel data from the output of the Inverse Fast Fourier Transform IFFT into serial form. To transmit the data, it is converted in the form of a serial sequence so that it can be transmitted via the AWGN channel. This is due to cost savings. If you don't convert to serial form, you need many channels according to the number of carriers. By arranging in series, only one channel is needed to transmit the data. The process of changing parallel data to serial.

Additive White Gaussian Noise (AWGN)

In this block the signal will pass through the noise channel in the form of AWGN and will experience a change in the polarization of the signal that will be received at the receiver, it can also be categorized as noise as interference but in this concept, this noise is in the form of modulated sound which becomes an information signal.

Serial to Paralel (S/P)

This block aims to change the data received from the transmitter that has passed through the AWGN channel, so the series of discrete serial signals will be parallelized for the FFT process so that it can be demodulated into the initial signal when sent.

Fast Fourier Transform (FFT)

The FFT block functions as a local oscillator at the receiver which separates the carrier frequency from the different OFDM symbols on that frequency. The number of FFT points is the same as the number of IFFT points.

MPSK Demodulator

The OFDM symbol which is still in MPSK modulation format is then converted into binary data.

Paralel to Serial (P/S)

The binary data which is still in the form of a parallel data stream is then converted into a serial data stream. The process of changing parallel data into serial.

Combiner

This block is intended where the signals received at each receiver antenna will be recombined. In this block, basic linear operations such as adding multiplication, and conjugate transformations to the received signal are carried out to reduce noise.

Space-Time MLSE Decoder

Space-Time MLSE Decoder generally functions to convert space-time trellis code symbols into a sequence of data bits. The data bits are obtained by using the Maximum Likelihood Algorithm. The Maximum Likelihood Algorithm is a complex signal detection. This ML algorithm is implemented through the Viterbi Detection Algorithm. The ML principle is to choose the smallest Hamming code distance (hard decoding) or based on the Euclidian distance dmin2 (soft decoding) of two pairs of codewords (2L).

Output Data

Output data in the form of data that has been affected by AWGN noise which has become digital signals, data that is the output of the Space-Time MLSE decoder in the form of binary bits which will be compared with the data when it enters the system to see the probability level or bits the error.

RESULT AND DISCUSSION

ANALYSIS OF SIMULATION RESULTS

IV.1. Simulation Parameters

The main purpose of this simulation is to determine the performance of MIMO-OFDM with the Space-Time Trellis Code (STTC) technique which is based on Bit Error Rate (BER) and Throughput.

TABLE 4.1 shows that the modulation techniques used in the MIMO-OFDM system are QPSK, 8PSK, and 16PSK. The number of transmitter antennas is 2 which means that the antenna uses multiple inputs. The number of receiver antennas is 2 which indicates the use of multiple output antennas. Error control coding uses convolutional encoding with code rate which states the ratio of the number of input bits to the number of output bits in the encoding process. The number of carriers for the MIMO-OFDM system is 8 and 16. The number of FFTs is 32, 64, and 128.

The system in the simulation has parameters as shown in TABLE 4.1.

TABLE 4. 1. MIMO-OFDM System Parameters with STTC

Parameter System	Parameter Value
Bit	76800
SNR	1 - 25
Troughput	0 – 500 kbps
Modulation Technique	QPSK, 8PSK, and 16PSK

Parameter System	Parameter Value
Tx Antenna	2
Rx Antenna	2
Error Control Coding	*Convolutional coderate ½*
Numbers of Carrier	8 and 16
FFT Size	**32, 64, and 128**

IV.2. Space-Time Trellis Code (STTC) Simulation Scenario on MIMO System

The program will display the simulation results of Space-Time Trellis Code (STTC) on the MIMO OFDM system using MATLAB R2008a with Windows Vista Ultimate OS with 8Gb RAM capacity. Where the main display of the Graphic User Interface (GUI) is in FIGURE 4.1 as follows:

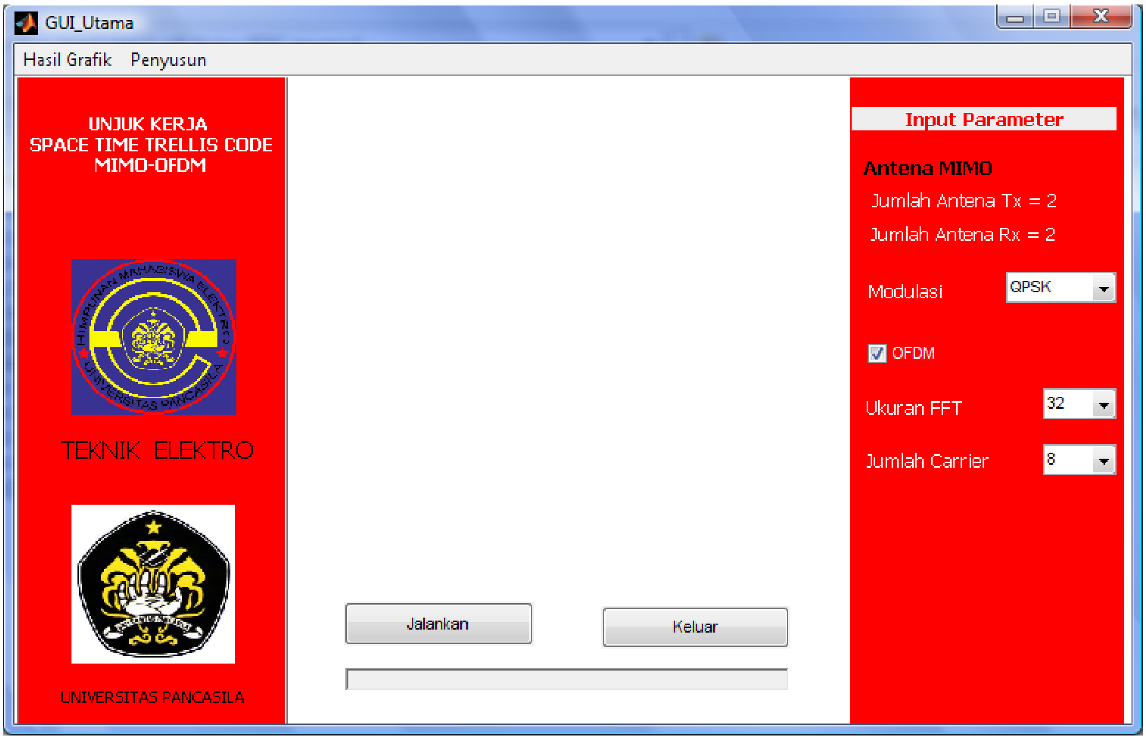

FIGURE 6. GUI of the simulation

IV.3. Simulation Results from Comparison of BER vs SNR and system throughput on the effect of using OFDM on system performance with QPSK, 8PSK, and 16PSK modulation.

For BER and throughput on systems without using OFDM compared to systems that have used OFDM on system performance with QPSK, 8PSK, and 16PSK modulation.

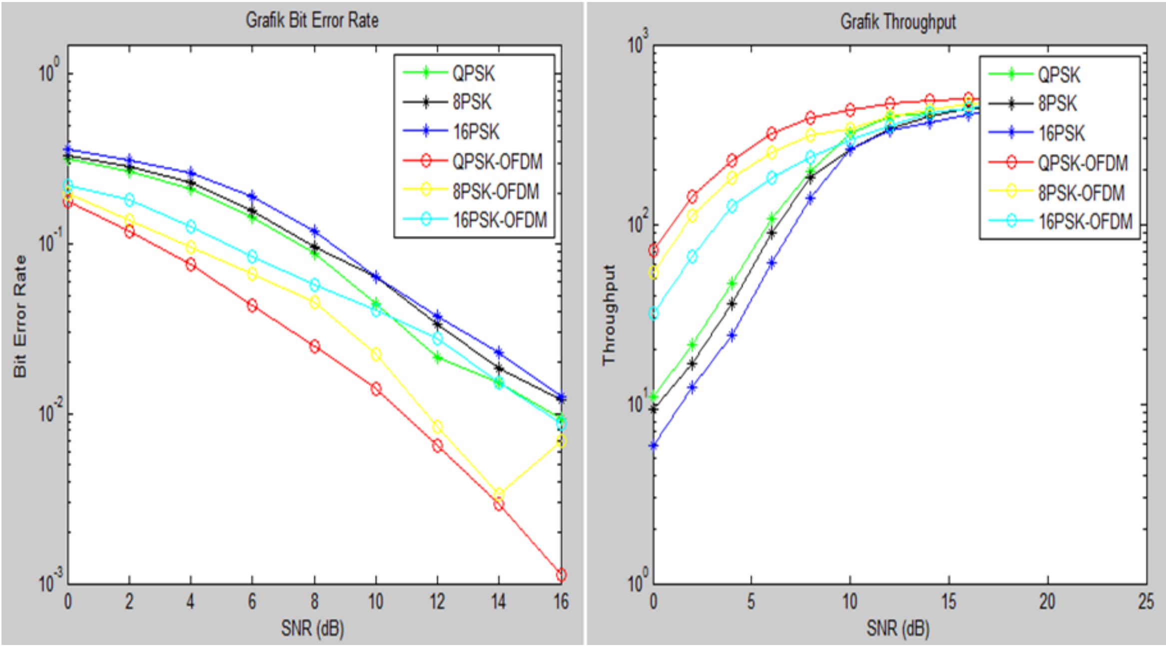

FIGURE 7. BER vs SNR and Throughput graph on the effect of OFDM usage on system performance with QPSK, 8PSK and 16PSK

In FIGURE 7, it can be seen that the effect of OFDM and the modulation used in the system is very large, as evidenced by the differences that occur between the BER and throughput values in systems without using OFDM and systems using OFDM with different modulations, namely QPSK, 8PSK, and 16PSK. From the graph, it can be seen that the system with QPSK modulation and using OFDM has better performance than the others because QPSK experiences the least distortion between 8PSK and 16PSK modulation, coupled with OFDM which allows efficient use of bandwidth so that the number of bit errors can be minimized. The comparison of BER and throughput values on the effect of using OFDM on system performance with QPSK, 8PSK, and 16PSK modulation can be seen in TABLE 4.2 and 4.3.

TABLE 4.2 Comparison of BER values on the effect of using OFDM on system performance with QPSK, 8PSK, and 16PSK modulation.

SNR	BER (tanpa OFDM)			BER (dengan OFDM)		
(dB)	QPSK	8PSK	16PSK	QPSK	8PSK	16PSK
0	0,317969	0,329036	0,359505	0,176823	0,199609	0,220833
4	0,211241	0,231641	0,261372	0,075998	0,096832	0,128168
8	0,088411	0,096701	0,118924	0,025043	0,045226	0,045486
12	0,021701	0,033377	0,037891	0,006467	0,008464	0,021571
16	0,009418	0,012153	0,012717	0,001128	0,006988	0,008681

TABLE 4.3 Comparison of throughput on the effect of using OFDM on system performance with QPSK, 8PSK, and 16PSK modulation.

SNR	Troughtput (tanpa OFDM)			Troughput (dengan OFDM)		
(dB)	QPSK	8PSK	16PSK	QPSK	8PSK	16PSK
0	10,88962	9,246114	5,80933	71,43363	53,94981	31,86286
4	46,60275	35,8603	24,16743	226,8286	180,5749	126,8516
8	198,1338	180,8354	140,9632	387,9921	314,7583	237,3782
12	396,8916	339,793	335,2223	468,5899	402,0336	356,0758
16	442,4537	439,933	405,2553	494,3862	466,1392	444,2064

IV.4. Simulation Results from Comparison of BER vs SNR and Throughput on the effect of carrier changes on system performance with QPSK and FFT 128 modulation.

For BER and throughput on the effect of carrier changes on system performance with QPSK and FFT128 modulation can be seen in FIGURE 8.

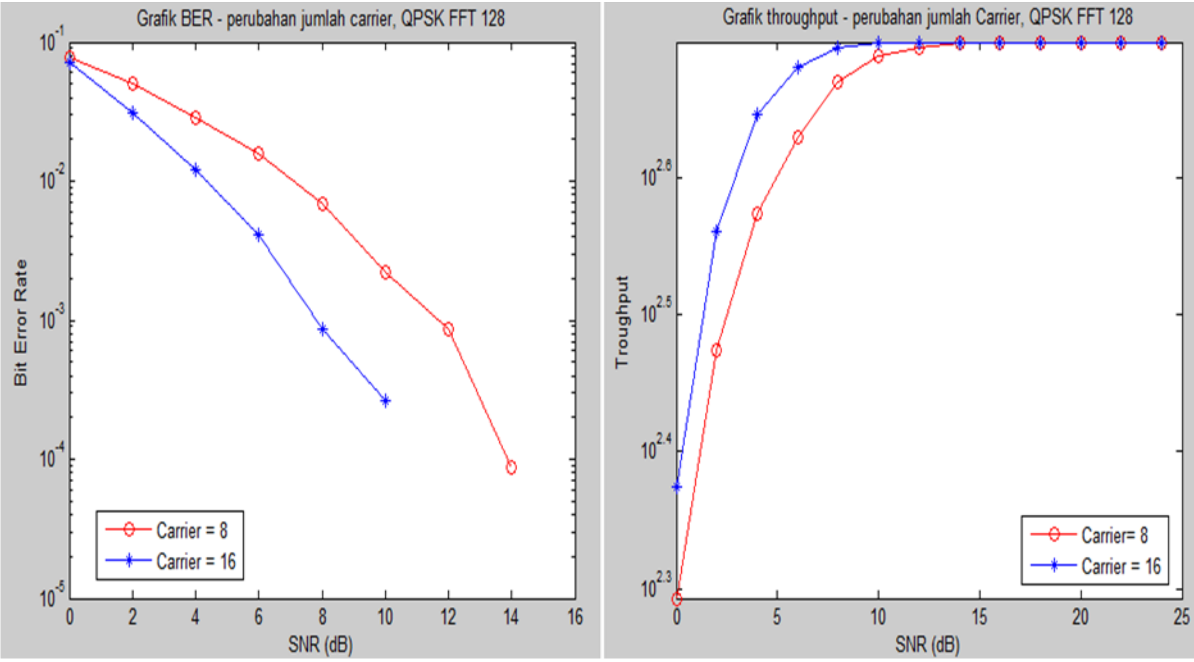

FIGURE 8. Graph of BER vs SNR and Throughput on the effect of carrier changes on system performance with QPSK and FFT128 modulation

In FIGURE 8, BER vs. SNR for changes in the number of carriers in the system can be seen that the BER changes are getting smaller when the number of carriers is doubled from the previous number of carriers. Likewise, changes in system throughput when the number of carriers is increased, the system throughput is getting better when compared to the number of carriers which is smaller than the number of carriers being increased, although in this graph the throughput difference in the system is not too large. In addition, when the system with QPSK modulation and carrier16 is at the SNR = 12 point and the system with carrier 8 is at the SNR = 16 point the line on the graph is broken due to the error that occurs less than 10^{-5} so the simulation program assumes that the system does not have an error in bits sent. Therefore, when BER = 0 then the system throughput will be a maximum of 500kbps. The comparison of BER and throughput in FIGURE 8 can be seen in TABLE 4.4 and 4.5.

TABLE 4.4 Comparison of BER on the effect of carrier changes on system performance with QPSK and FFT128 modulation.

SNR (dB)	BER	
	Carrier 8	Carrier 16
0	0,077431	0,072092
4	0,028299	0,012023
8	0,006771	0,000868
12	0,000868	0
16	0	0

TABLE 4.5 Comparison of system throughput to changes in the number of carriers in MIMO OFDM with 128. QPSK and FFT modulation.

SNR (dB)	Troughput (Kbps)	
	Carrier 8	Carrier 16
0	196,3487	236,6024
4	375,2306	443,0372
8	467,1589	495,6766
12	495,6766	500
16	500	500

IV.5. Simulation Results from Comparison of BER vs SNR and Throughput on the effect of changes in FFT on system performance with QPSK and carrier modulation16.

For BER and throughput on the effect of changes in FFT on system performance with QPSK and carrier16 modulation can be seen in FIGURE 9.

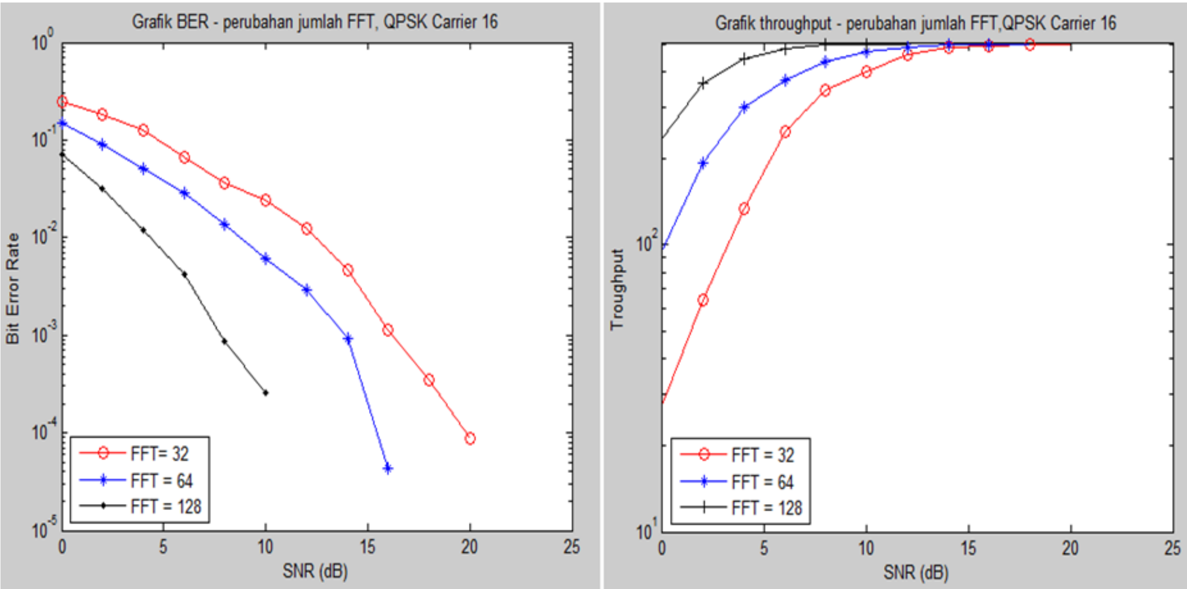

FIGURE 9. Graph of BER vs. SNR and throughput on the effect of changes in FFT on system performance with QPSK and carrier modulation16

In FIGURE 9, the BER vs SNR graph for changes in the size of the FFT on the system with QPSK and carrier16 modulation shows that the BER value of FFT64 is better than FFT32, as well as FFT128 is better than FFT64 and FFT32 because the larger the size of the FFT, the better the signal processing that occurs. Likewise, changes in system throughput when the size is FFT128, the system throughput is getting better when compared to systems using FFT64 and FFT32 sizes. In addition, when the system with QPSK and FFT128 modulation is at the SNR = 12 point the line on the graph is interrupted due to the error that occurs less than 10^{-5} so that the simulation program assumes that the system does not have an error in the bit sent. Therefore, when BER=0 then the system throughput will be a maximum of 500kbps. The comparison of BER and throughput in FIGURE 9 can be seen in TABLE 4.6 and 4.7

TABLE 4.6 Comparison of BER on the effect of changes in FFT on system performance with QPSK modulation and 16 carriers.

SNR (dB)	BER

	FFT 32	FFT 64	FFT 128
0	0,249783	0,151259	0,072092
4	0,124262	0,05	0,012023
8	0,036372	0,013845	0,000868
12	0,012543	0,002865	0
16	0,001128	4,34E-05	0

TABLE 4.7 Comparison of system throughput against changes in FFT in MIMO OFDM with QPSK modulation and 16 carriers.

SNR (dB)	Troughput (kbps)		
	FFT32	FFT64	FFT128
0	28,23834	96,98922	236,6024
4	132,6512	299,3685	443,0372
8	345,1964	434,9303	495,6766
12	459,2582	485,8603	500
16	4943862	499,783	500

IV.6. Simulation Results from Comparison of BER vs SNR and throughput on the effect of changes in modulation on system performance with FFT128 and carrier16.

For BER and throughput on the effect of changes in modulation on system performance with FFT128 and carrier16 can be seen in FIGURE 10.

In FIGURE 10, the BER vs SNR graph for changes in modulation in the system with FFT128 and carrier16 shows that the BER value in the system with QPSK modulation is smaller than the system with 8PSK and 16PSK modulation because the number of 8PSK and 16PSK signal constellations is more than QPSK so that distortion occurs on 8PSK and 16PSK modulation is bigger than QPSK modulation. Likewise, the throughput of the system with QPSK modulation is better than the system with 8PSK and 16PSK modulation. In addition, when the system with QPSK modulation is at the SNR=12 point, 8PSK and 16PSK are at the SNR=16 point the line on the graph is interrupted due to the error that occurs less than 10^{-5} so that the simulation program assumes that the system does not have an error in the bit. sent. Therefore, when BER = 0 then the system throughput will be a maximum of 500 kbps. The comparison of BER and throughput in FIGURE 10 can be seen in TABLE 4.8 and 4.9.

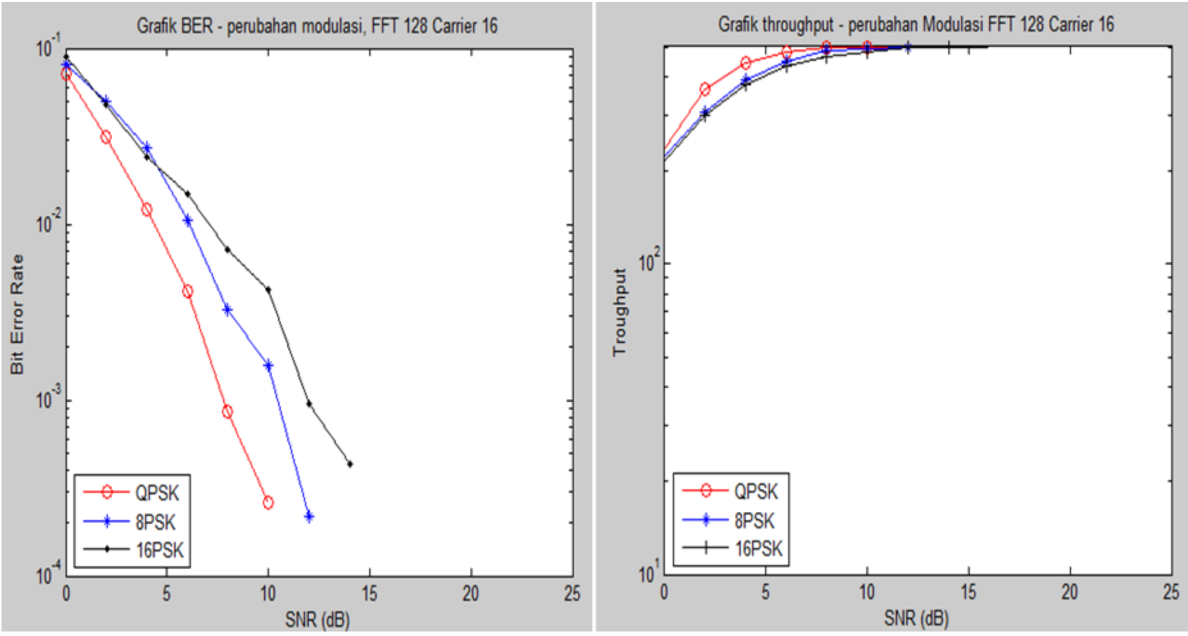

FIGURE 10. Graph of BER vs. SNR and throughput on the effect of changes in modulation on system performance with FFT128 and carrier 16

TABLE 4.8. Comparison of BER on the effect of modulation changes on system performance with FFT128 and carrier16

SNR (dB)	BER		
	QPSK	8PSK	16PSK
0	0,072092	0,080556	0,089236
4	0,012023	0,027344	0,024306
8	0,000868	0,003255	0,007161
12	0	0,000217	0,000955
16	0	0	0

TABLE 4.9. Comparison of system throughput on changes in the modulation of system performance with FFT128 and carrier16.

SNR (dB)	Troughput		
	QPSK	8PSK	16PSK
0	236,6024	223,337	215,8862
4	443,0372	390,9384	378,9342
8	495,6766	483,9603	465,3249
12	500	498,916	495,2462
16	500	500	500

CONCLUSION

From the results of the simulation and analysis that has been carried out, several conclusions are obtained related to the performance of the MIMO-OFDM Space-Time Trellis Code (STTC), namely:

1. The use of OFDM in Space Time Trellis Code-MIMO can reduce BER and increase system throughput when compared to systems without OFDM.
2. The larger the number of carriers used in the system with the same FFT size, the smaller the BER generated so that the system throughput is getting better.
3. The larger the size of the FFT used in the system with the same number of carriers, the smaller the BER generated so that the throughput of the system is getting better.
4. QPSK modulation gives the best performance when compared to 8PSK and 16PSK modulation.

5. The smallest BER and the largest throughput are obtained when using QPSK and OFDM modulation with carrier16 and FFT128, namely BER=0.072092 and throughput=236.6024 when SNR=0.

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