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Implementation and Performance Analysis of Convolution Codeon WARP (Wireless Open Access Research Platform)

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***Abstract*—In order to have a reliable and robust data transmission in digital communication system, channel coding is applied for improving the performance of the system. Convolutional code is one of channel coding technique for error detection and error correction. In this paper, convolutional code is used for improving the bit error rate (BER) performance in *Quadrature Phase Shift Keying* (QPSK)modulation scheme which is implemented on a *Wireless Open-Access Research Platform* (WARP). Based on implementation and measurement results show that with an equal transmit power (with Tx gain =20dB), QPSK modulation with convolutional code have a lower BER than the uncoded one. For convolutional code with rate =1/2 at a range of 6 meter has a BER value of 0.00065232 while the uncoded BER is 0.0048828. By comparison of the system performance with different coding rate (1/2,2/3,3/4.5/6 and 7/8), the BER performance of QPSK system with convolutional code rate of 7/8 is better that the others. It can achieve a BER of 0.00037495.**

Keywords*—*Convolutional-codes; QPSK; WARP.

I. Introduction

Digital communication system nowadays needs to have the ability to provide a reliable and robust data transmission. One of the parameter affecting the system performance is the channel noise. The noise value of the channel is affecting the signal to noise ratio (SNR). This noise disturbance can bring to a signal distortion. To have a system that highly resistance to noise, error control coding is needed to improve the system performance in term of reducing the bit error rate parameter. Convolutional code is one of channel coding technique for error detection and error correction [2,4]. By using convolutional code technique with a specified code ratewill affecting the bit error rate (BER) value.

Quadrature Phase Shift Keying (QPSK) is one of modulation technique that has a bandwidth efficiency twice higher than BPSK, because each modulated symbols consist of two bits data. This paper explained a convolutional code in QPSK modulation scheme using a *Wireless Open-Access Research Platform* (WARP)module which is a *Software Defined Radio* (SDR) module for wireless communication system that can be configurable and controlled through a software. By using SDR, can replace some hardware functionality so it can reduced the cost, minimize error and it is programmable. WARP is used as a transmitter and receiver to measure the performance of convolutional code to improve the BER of QPSK modulated system.

This paper is described in order as the following: the first part is introduction, the second part is explaining about theory of convolutional code. The system planning on WARP module is explained in part III and the next part is the measurement result and analysis, and finally some conclusion on convolutional code performance in improving BER of QPSK modulation system.

II. Theory

A. Convolutional Code [9][10][11]

Convolutional code is one of the common channel coding technique. Chanel coding or usually called error correcting code can provide a reliable communication system. Convolutional code protect the information by adding parity bits, a rate of k/n convolutional code processed a k-bit sequence with one or more shift register (with a feedback). Convolutional code processed each of n bit symbol (n>k) output sequence from linear operation of the input symbol [8]. Convolutional code encoder with a code rate of 1/2 can be seen in Figure 1 below:

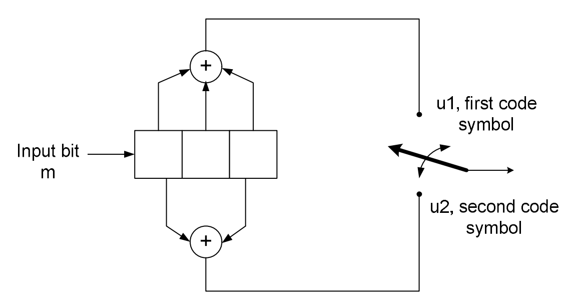

Figure 1. Convolutional code encoderwith length K=3and *code rate* ½

Convolutional code encoder with length K = 3 and code rateof 2/3 is shown in Figure 2.

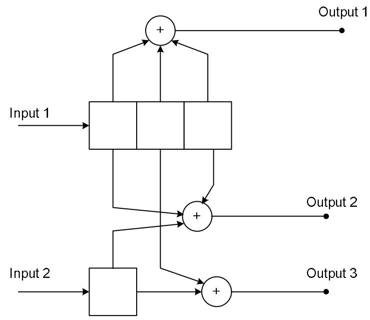

Figure 2 Convolutional code encoder with length K = 3 and code rate 2/3

Convolutional code encoder with length K = 3 and code rate of ¾, 5/6 and 7/8 can be seen in Figure 3, Figure 4 and Figure 5 respectively.

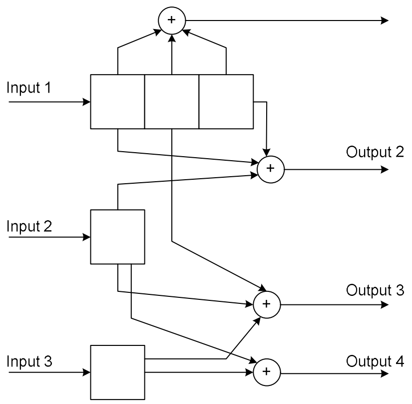

Figure 3 Convolutional code encoder with length of K=3 and code rate of 3/4

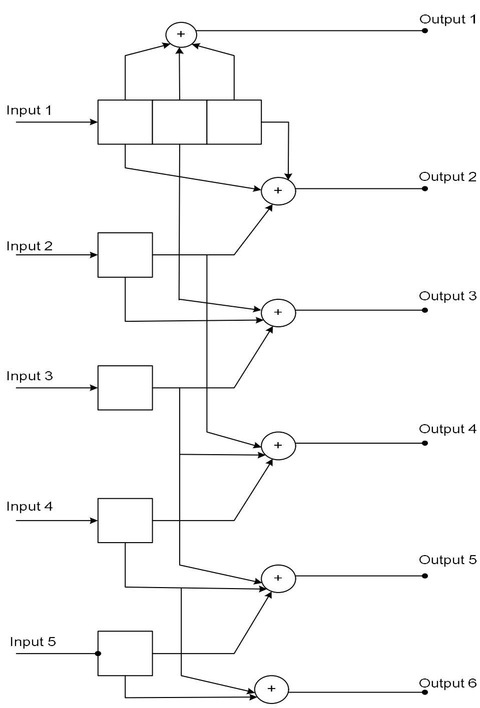

Figure 4Convolutional code encoder with length of K=3 and code rate of 5/6

Some important parameters in convolutional code:

1. Convolutional code rate (R)

Convolutional code rate(R) is a ratio between input information bit and coded bit output with a formula as follow:

$$R = \frac{k}{n}$$

Dengan, R = Convolutional code rate
k = number of input bits
n = Number of output bits

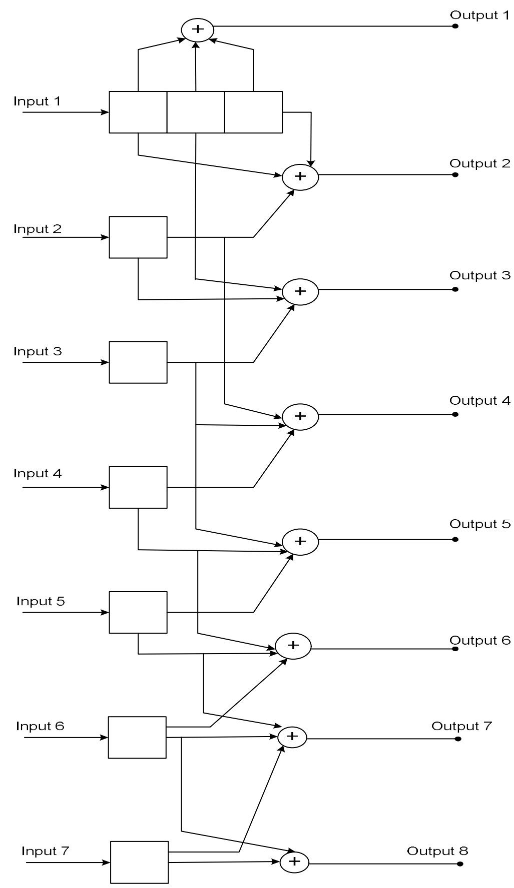

Figure 5 Convolutional code with K=3 and code rateof 7/8

2. Constraint length (K)

Constraint length, K, is the number of shift register element in convolutional code encoder. The memory length is defined as K=M+1. With M is the maximum polynomial degree of the encoder transfer function.

B. Viterbi Algorithm

Viterbi Algoritm is a decoding methods for convolutional code. It used trellis diagram as seen in Figure 6. On the receiver side, Viterbi decoder attempts to correcting the signal error by saving some previous data, calculate the constellation distance between a data series and predict the most probable received data so an error can be detected and corrected. By using

Hamming distance, the error metric can be calculated for each state [6].

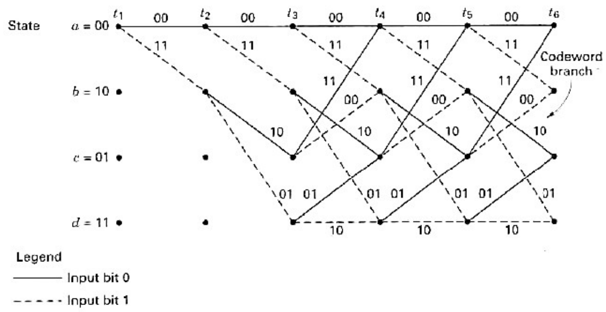

Figure 6 Trellis Diagram with code Rate of 1/2 and K=3

C. *Quadrature Phase Shift Keying (QPSK)[8]*

Quadrature Phase Shift Keying (QPSK) modulation is an M-ary encoding where M=4 (Quartenary). QPSK modulation has four signals that represent four binary codes, and each signal has a phase different of 90^0.

Tabel The possible state in QPSK modulation can be seen in table 1 as follow:

Table1. The possible state in QPSK Modulation

Fase	Data Biner
45^0	00
135^0	01
225^0	11
315^0	10

QPSK modulation has a bandwidth efficiency twice than BPSK, because one modulated symbol consist represent two bits. Constellation diagram of QPSK is shown in Figure7.

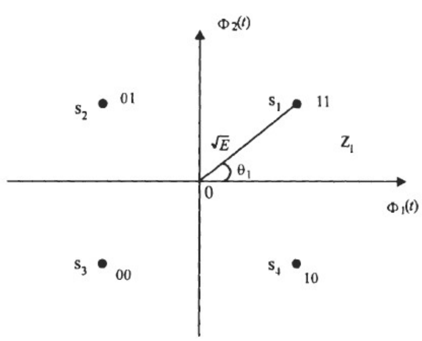

Figure 7 QPSK constellation diagram

D. *Coding Gain[9]*

Coding gain is a parameter for measuring the signal-to-noise ratio (SNR) of uncoded and coded system that is need by the system to achieve the same bit error rate (BER). For example, an uncoded BPSK modulation system in AWGN channel has a BER of $10^{-2}$when the SNR is 4 dB, and for a coded one, can achieve the same BER using SNR of 2.5 dB, the the coding gain would be 1,5 dB (4 dB - 2,5 dB).

E. *Wireless Open-Access Research Platform (WARP)*

WARP is a programmable radio device that can be programmed for making wireless network prototype. WARP is combining some high ability device that can be programmed using a*repository open-source* [5].

WARP has four radio board that can be arranged separately can be seen in Figure8. Each acts as a transceiver that has its own registry.

Figure8 WARPRadio Board

III. System Design And Implementation

A. *Communication system modeling*

Generally, communication system with convolutional code block diagram is described in Figure 9.It is similar with other SISO communication system, where on the transmitter side, after bit is generated using convolutional code witha specified code rate and then modulated using QPSK modulation and transmitted through the channel. At the receiver side, after demodulation process, the Viterbi decoder obtained the output decoded bits. The next step is calculate the BER by comparing the input bits before encoder and the output bits after decoder.

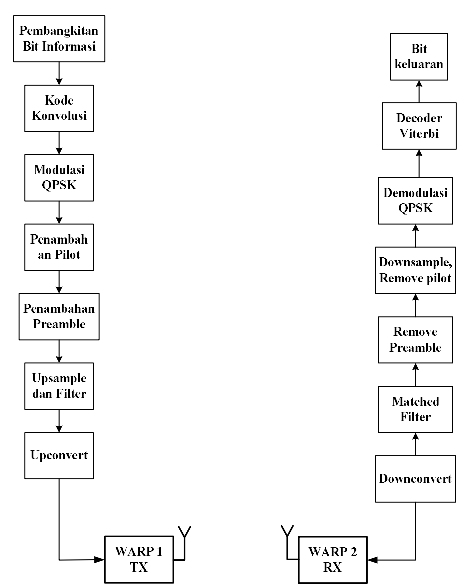

Figure 9 SISO Communication system block diagram using convolutional code and QPSK Modulation technique.

B. Implementation on WARP module

To implement a communication system on WARP board, an integration between PC controller and the WARP module must be established first. Each WARP node is connected to a PC/latop using network cable to a network switch as seen in Figure 10.

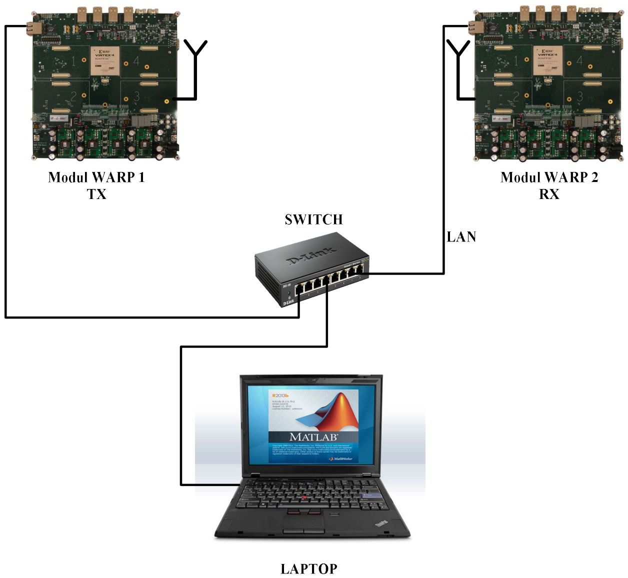

Figure 10 SISO Communication system configuration using WARP

C. BER Analysis

BER analysis is done by comparing between the received output bits of the Viterbi decoder and the input bits of the convolutional code encoder.

IV. Measurement Results And Analysis

Analysis of QPSK system with convolutional codes performance is done based on indoor measurement. The measurement scenario is to test the system performance whether in line of sight (LOS) or non-line of sight (NLOS) condition, by giving a variation on the distance between the transmitter node and the receiver node. The second scenario that also discussed in this paper is the performance test of the system by using a different transmit power level so the BER value for different Tx-Rx length and for different SNR value can be obtained.

The first part of the analysis is for comparison of the system performance in LOS and NLOS condition, the second scenario is to shows the system performance using convolutional code compared to the uncoded one, and the third scenario is to see the performance of the system which using a different coding rate of the convolutional code.

A. System performance in LOS and NLOS condition

Table 2 BER result in LOS and NLOS Condition for 6 meter length using Convolutional code withCode rateof1/2

TABLE I. Tx_ Gain_Rf (dB)	TABLE II. OS	TABLE III. NL OS
TABLE IV. 0	TABLE V. (.18587	TABLE VI. 0.42 14
TABLE VII. 4	TABLE VIII. (.15788	TABLE IX. 0.36 92
TABLE X. 8	TABLE XI. (.076321	TABLE XII. 0.26 88
TABLE XIII. 12	TABLE XIV. (.022179	TABLE XV. 0.16 57
TABLE XVI. 16	TABLE XVII. (.0078278	TABLE XVIII. 0.04 83
TABLE XIX. 20	TABLE XX. (.00065232	TABLE XXI. 0.02 02
TABLE XXII. 24	TABLE XXIII. (	TABLE XXIV. 0.00 65
TABLE XXV. 28	TABLE XXVI. (	TABLE XXVII. 0.00 33
TABLE XXVIII. 3 2	TABLE XXIX. (	TABLE XXX. 6.52 E-04
TABLE XXXI. 36	TABLE XXXII. (	TABLE XXXIII. (

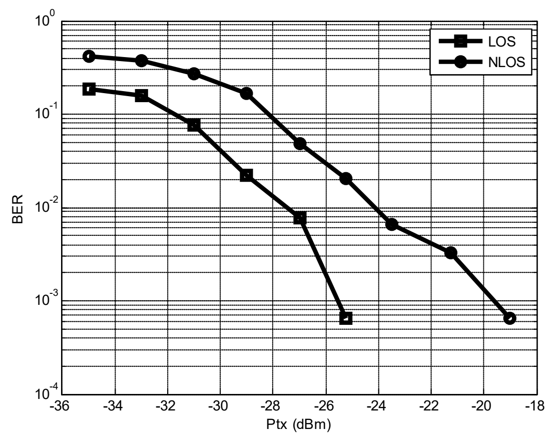

Figure 11 BER of the system in LOS and NLOS condition for 6 meter length and convolutional code rate of 1/2

From table 2 above, it can be seen that in LOS condition, a zero BER value achieved when the transmitter power gain is -24 dB, while in NLOS condition, the transmitter power of -36 dB is needed to achieved the same BER value. Or in other way of saying, for NLOS condition, in order to get the same BER performance with LOS condition, 12 dB power gain must be provide for the system.

Figure 11 shows the system BER performance in LOS and NLOS condition with Tx-Rx distance of 6 meter. The graphic result shows that a zero BER can be obtained using transmit power of -25.2dBmfor LOS and -19 dBm for NLOS condition. So approximately 6 dB gain is needed if NLOS condition is occurred, to achieve the same BER performance of the system in LOS condition.

Table 4 Measurement result of QPSK system using Convolutional code for 6 m distance

Tx_Gain_RF	Rate 1/2	Rate 2/3	Rate 3/4	Rate 5/6	Rate 7/8
0	0.18587	0.17189	0.18475	0.14499	0.16085
4	0.15788	0.11998	0.12026	0.11159	0.13011
8	0.076321	0.044074	0.075381	0.058546	0.094863
12	0.022179	0.01714	0.018301	0.021218	0.026622
16	0.0078278	0.0048972	0.0056645	0.005501	0.0052493
20	0.00065232	0.00048972	0.00043573	0.00039293	0.00037495
24	0	0	0	0	0
28	0	0	0	0	0
32	0	0	0	0	0
36	0	0	0	0	0

B. The system performance comparison while using convolution code and uncoded

Table 3 BER measurement result of Convolutional Code Rate of 1/2

Tx_Gain_Rf (dB)	Rate 1/2	Tanpa Code
0	0.18587	0.24984
4	0.15788	0.16112
8	0.076321	0.09375
12	0.022179	0.040039
16	0.0078278	0.029297
20	0.00065232	0.0048828
24	0	0.00032552
28	0	0
32	0	0
36	0	0

From table 3 and Figure 12, can be seen that convolutional code can improve the BER performance of QPSK system for Tx-Rx distance of 6 meter. Using convolutional code with code rate of ½, zero BER is achieved using transmit power of -23.5 dBm, while using the same transmit power, the uncoded one achieved BER value of 0.00032552. It also can be viewed from the Figure 12 that the coding gain for convolutional code with code rate of ½ for BER value of 10^{-3}equals to -24.4 dBm – (-25.6) dBm = 1.2 dB.

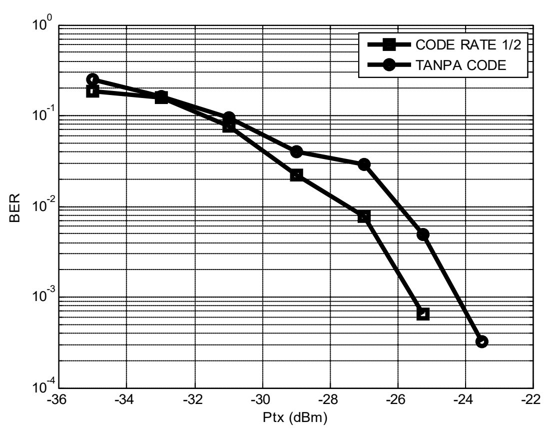

Figure12. BER comparison between QPSK using convolutional code with code rate of ½ and uncoded

C. Performance of QPSK system using convolutional code with code rate of 1/2, 2/3, 3/4, 5/6 and 7/8

Indoor measurement result of QPSK system implemented on WARP using convolutional code of 1/2, 2/3, 3/4, 5/6 and 7/8 in 6 meter length is shown in Table 4. And the graphic presentation is depicted in Figure13.It shows that convolutional code with code rate of 7/8 has a smaller BER value compared to the others. When the transmitter gain reference is 20 dB, and the transmit power is -25.2 dBm, the performance of convolutional code with code rate of 7/8 gives a BER value of0.00037495, while the other rate achieved a higher BER value.

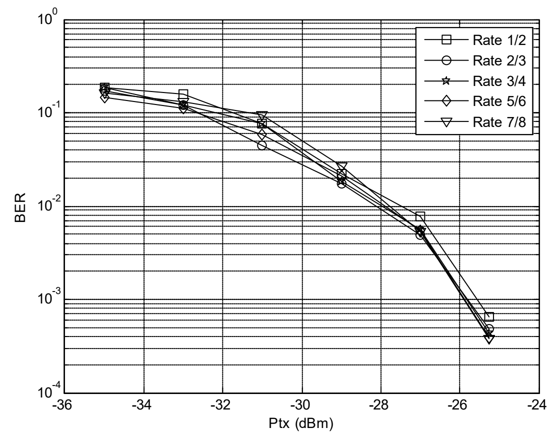

Figure 13 BER of QPSK system using a different code rate of convolutional code for 6 meter distance.

V. CONCLUSION

Based on the implementation result and analysis, QPSK system implemented on WARP using convolutional code can give a smaller BER value compared to the uncoded one. For convolutional code with code rate of ½, a coding gain of 1.2 dB is obtained to achieve a BER value of 10^{-3}.

Transmit power is affecting the BER performance, the higher the transmit power, the better the BER value. This happens whether it is in a LOS or NLOS condition. The further the distance, BER performance is getting worse.

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