

# Performance of Coded Modulation in Multicarrier CDMA System

Linda Meylani\*, Nur Andini, Iswahyudi Hidayat

School of Electrical Engineering, Telkom University  
Jl. Telekomunikasi no 1, Trs. Buah Batu, Bandung 40257, Indonesia  
e-mail:lindameylani@telkomuniversity.ac.id

## Abstract

*Coded modulation scheme introduce robust and reliable system. It combine coding and modulation in one system. This paper show performance of coded modulation with coding rate 2/3, using 8PSK and convolutional coding that implemented in MC CDMA system. MC CDMA is one of multicarrier system that combine OFDM and CDMA so its offer reliable system in frequency selective fading. Decoding process for coded modulation is done by using log likelihood ratio for least significant bit (define the subset) and the entire bits (member of subset). Simulation result shown that coded modulation in MC CDMA system have a good performance in flat fading and frequency selective fading.*

**Keywords:** *trellis coded modulation, euclidean distance, soft decision, Viterbi decoding, multicarrier*

## 1. Introduction

The most concerning issues in digital communication are reliability, higher data rate and bandwidth efficiency. Reliable system can be achieved using error control coding such as convolutional coding, turbo coding, ldpc, etc. But in the other side, the use of error control coding can cause data size becomes larger and it must be supported with larger bandwidth. As the reliability of systems that can be obtained by using error control coding, high data rate can be obtained by using a specific modulation type. To maintain system performance, transmission with high data rate must be supported with large bandwidth. Ungerboeck in [1], [2], [3], introduce Trellis Coded Modulation (TCM) that combine forward error correction usually using convolutional code and modulation techniques. This technique can improve robustness and reliability of system without requiring additional bandwidth or reducing data rate. Trellis coded modulation combine error control coding, usually convolutional coding, with coding rate  $k/(k+1)$  and modulation with  $2^{k+1}$  level. This technique offers robust system with limited bandwidth.

When the system works on a frequency selective channels, the received signal power level will more fluctuate and interference intersymbol (ISI) became higher. These phenomenon can make degradation in system performance. One technique that can be used to mitigate the effect of frequency selective fading is multicarrier, include orthogonal frequency division multiplexing (OFDM) and multicarrier code division multiplexing (MC-CDMA). OFDM and MC CDMA will transmit data in  $N$  parallel subcarrier. Carrier signal on each subcarrier orthogonal to each other to avoid ICI. Some research also have done to analysis performance TCM, Zehavi in [4] analyse performance of TCM using 8 PSK in rayleigh fading channel. In this paper, Zehavi introduced the use of bits interleaver to improve TCM performance in rayleigh channel. Martin Papez in [5] simulate TCM using convolutional code system by using MATLAB Simulink and show its performance in AWGN channels. Samreen Amir and Muhammad Asif in [6] analyse performance of TCM - MC CDMA over rayleigh fading channels. [6] also describe the effect of difference constraints length in TCM. [7] show performance TCM in OFDM system an used Artificial Neural Networks (ANN) for decoding process. [8] analyzed the problem of joining convolutional coding-mapper and labelling process.

This paper also discuss about TCM especially to know performance TCM in MC CDMA. The differences of this research with the previous are model system and decoding methode of TCM. In this paper, bits interleaver will be used on the system of TCM. Interleaver block placed between convolutional coding and mapper. Decoding process is done by separating lsb and entire bits of the received symbol.

**2. Model System**

Model system in this paper are shown in figure 1. This model use Trellis Coded Modulation as error control coding with coding rate 2/3 and modulation 8 PSK. Trellis coded modulation in this system using block interleaver at the output of convolutional coding before mapping to 8 PSK. System performance has analyzed in flat frequency fading and frequency selective fading channel.

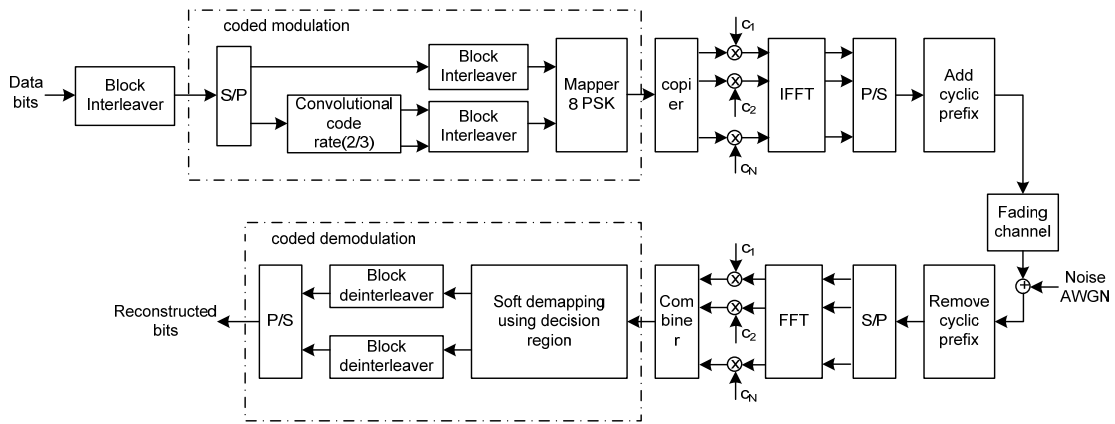


Figure 1. System Model

Interleaver is the first process in this system. All generated bit be interleaved use block interleaver with block size 20x3. Inteded use of interleaver is to avoid occurence of burst error. Input Coded Modulation in this system is 2 parallel bits, so output of block interleaver be divided to 2 parallel data. The first parallel data will interleave again using block interleaver and the second be an input of Convolutional coding with coding rate 1/2 and the output of convolutional code be an input of block interleaver. Figure 2 shown convolutional code that use in system model.

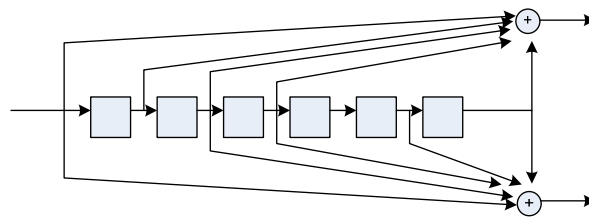


Figure 2. Convolutional code (rate 1/2)

Coding generator that used in convolutional code is  $g_1(D) = 171_8 = D^0 + D^1 + D^2 + D^3 + D^6$  and  $g_2(D) = 133_8 = D^0 + D^2 + D^3 + D^5 + D^6$ .

**2.1. Trellis Coded Modulation**

There is a difference in TCM mapping with convolutional mapping. TCM does not use gray code mapping but utilize natural binary mapping as shown in figure 3 for 8PSK.

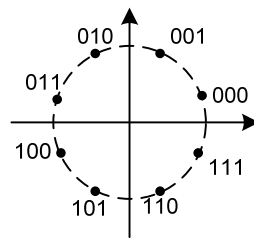


Figure 3. 8 PSK Constellation

There are three important steps in TCM mapping. First step is set partition/ selection, in this step, signal will divide into small subset with maximum euclidean distance between symbols intra subset. The second step is labeling, to represent the output encoder that have maximum euclidean distance. And the last step is code selection, to select the subset. In this step, least significant bit form bit constellation (8PSK) will used as selector to define the subset as subset 1 ( with b3 equal to 1) and subset 2 (with b3 equal to 0) as shown in figure 4.

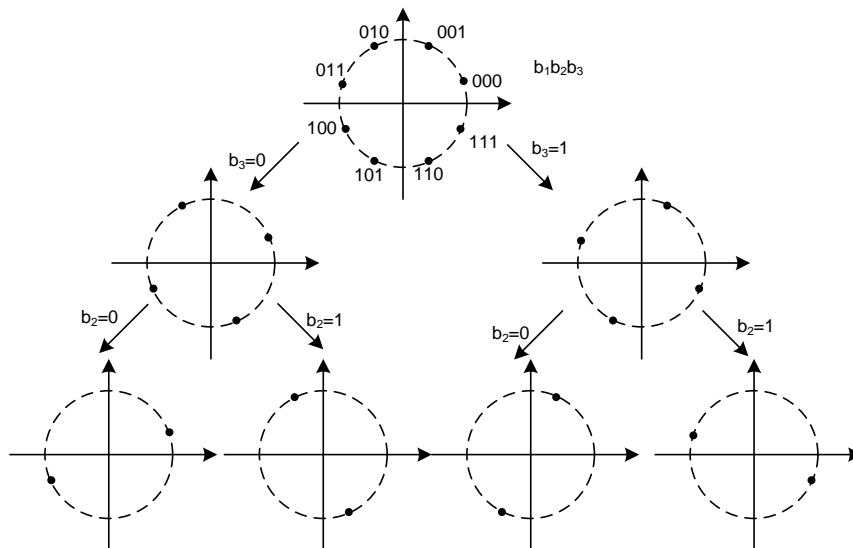


Figure 4. Set Partition/selection 8PSK [9]

Received symbol at receiver define as:

$$r = s + n \tag{1}$$

Where r is a received symbol, s is a transmit symbol and n is zero mean Gaussian noise with variance  $\sigma^2$ . Decoding process in the receiver use soft demapping scheme. This scheme has 2 step.

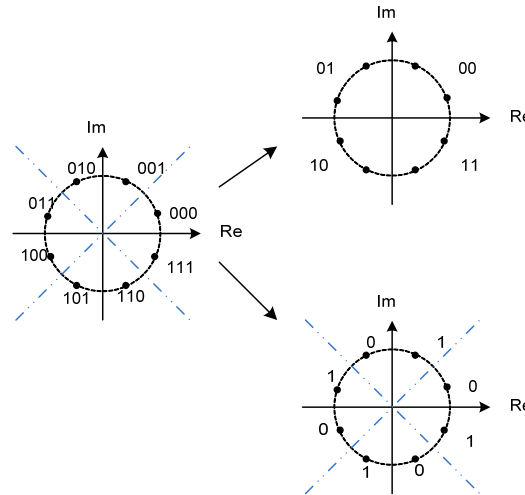


Figure 5. Define LSB bit and ith bit in subset

First step is to define least significant bit form the received symbol. Least significant bit will define the subset of signal. The second step is to define  $i^{th}$  bits in subset. If we assume that all symbols were transmitting with the same probability, the receiver can use Log likelihood ratio (LLR) algorithm to define bit  $i^{th}$  form receive signal  $r$ . LLR defines as [10] [11]:

$$\Lambda^{(i)}(r) = \ln \frac{Pr\{r|b^{(i)}(r) = 0\}}{Pr\{r|b^{(i)}(r) = 1\}} = \ln \frac{\sum_{s_k \in X_0(i)} p(r|s_k)}{\sum_{s_k \in X_1(i)} p(r|s_k)} \tag{2}$$

where  $i \in \{1, 2, \dots, m\}$  and  $b^{(i)}(s)$  define as  $i^{th}$  bit in label symbols.  $p(r|s_k)$  is define as [10]:

$$p(r|s_k) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{|r-s_k|^2}{2\sigma^2}\right) \tag{3}$$

After receiver has a soft bits that define  $i^{th}$  bit entire (2 bit msb), it must quantized interleaved and be an input for trellis decoding. The output of trellis decoding will combine with reconstructed lsb bits.

**2.2 Multi Carrier CDMA**

Multi carrier code division multiple access is a system that combine ofdm technique and CDMA system. There are two groups of MC CDMA, the first one, spreads the original bit message with spreading code sequence, and the other group spread serial to parallel converter bit message with spreading code sequence [12]. This system used first type of MC CDMA. Figure 5 shown MC CDMA system that used in model system.

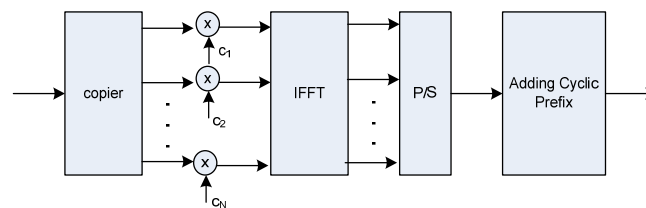


Figure 6. MC CDMA transmitter

Table 1. Simulation Parameter

Parameter	Value
Modulation type	8 PSK
Coding Rate Coded Modulation	2/3
Coding rate convolutional code	1/2
Generator convolutional code	$g_1(D)=171_8= D^0 + D^1 + D^2 + D^3 + D^6$ $g_2(D) =133_8= D^0 + D^2 + D^3 + D^5 + D^6$
Number subcarrier	128; 256
Cyclic prefix	1/4
Channel fading	Flat Rayleigh fading; frequency selective Rayleigh fading

**3. Results and Analysis**

To see the performance coded modulation on created model system, the system is tested with several scenarios:

- Compare performance of CM-MCCDMA system with 4PSK and 8PSK MC CDMA system (with/ without convolutional coding) at AWGN channel
- Compare performance CM-MCCDMA system at Rayleigh fading channel: frequency selective fading and flat fading
- Compare performance CM-MC CDMA at difference number subcarrier.

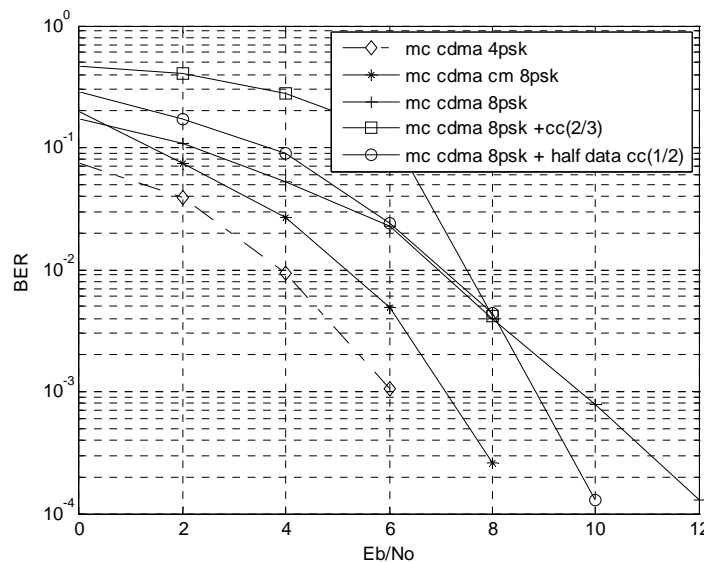


Figure 7. Compare Performance of coded modulation in AWGN

Samreen Amir in [6] show that constraints length give effect to the performance of TCM. Higher constraints length have better performance rather than lower constraints length. In this research, TCM is designed by using 7 as constraints length. Figure 7 show the performance of coded modulation scheme using 8 PSK in MC CDMA in AWGN channel with 128 subcarrier compared to MC CDMA using modulation with 4 PSK without using convolutional coding, and 8 PSK without using convolutional coding, 8 PSK using convolutional coding (with coding rate 2/3) and 8PSK with half data using convolutional coding (with coding rate 1/2). This figure shown coded modulation scheme using 8PSK have good performance than others but still below the performance of 4PSK. This is caused by the used of soft demapping to estimate bit  $i^{th}$  value from the subset. In soft demapping and decoding process, symbol received will estimate 2 msb in subset like 4PSK (figure 5) and quantized the estimate bit. Quantized bit be an input for trellis decoding. Symbol received will estimate lsb of the subset. After deinterleave process, estimated lsb bit and output of trellis decoding (2 bits) will combined to get reconstructed bits.

Performance of coded modulation in flat fading and frequency selective fading have shown in figure 8. This figure show that performance of coded modulation in flat fading is better than coded modulation in frequency selective fading. This is cause by multipath fading in frequency selective fading. Multipath with difference gain and delay, make signal received more fluctuative and more susceptible with noise. And it cause performance system become worse.

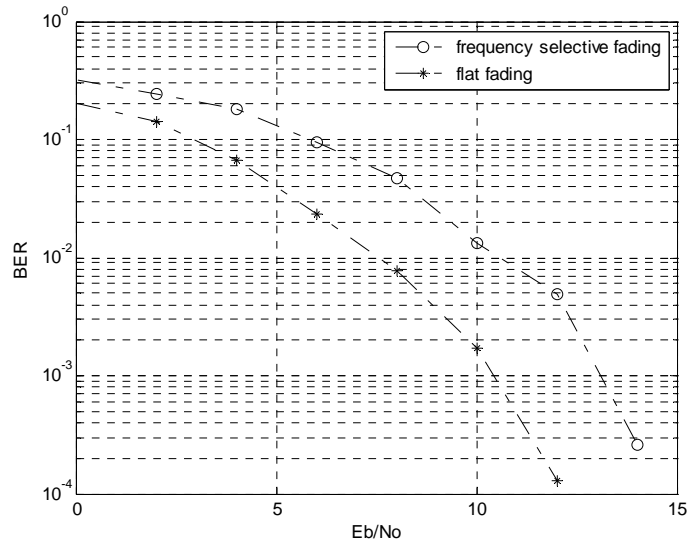


Figure 8. Performance coded modulation

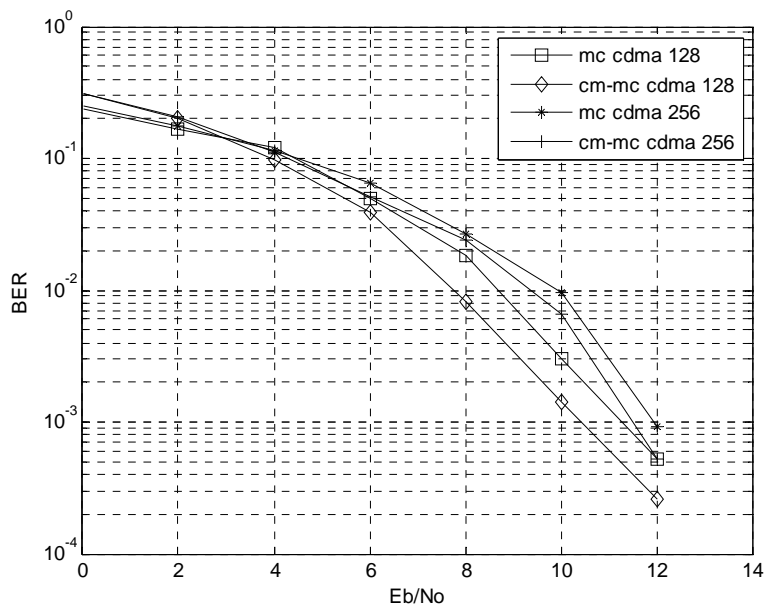


Figure 9. Performance coded modulation at frequency selective fading with difference number subcarrier

Figure 9, shown the performance of coded modulation in mc cdma with difference number of subcarrier at frequency selective fading. System simulated in 120km/hour. This figure show system with number subcarrier 128 have better performance than number of subcarrier 256. Larger number of subcarrier can make bandwidth on each subcarrier more smaller and

make system work like in flat channel. But larger number of subcarrier can make intercarrier interference higher, so it can make degradation in system performance.

#### 4. Conclusion

Coded modulation scheme in MC CDMA system has a good performance compare to another scheme 8 PSK in mc cdma. In AWGN channel, coded modulation can get  $10^{-3}$  at 7.2 dB (Eb/No level) difference 0.8 dB with 8PSK - convolutional coding (with coding rate 2/3) and difference 10.2 dB with 8PSK using convolutional code (coding rate 1/2) for half data. Using Log Likelihood Ratio (LLR) in soft demapping and decoding, and make system performance higher.

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