A COMPARISON BETWEEN FUSC AND PUSC SUB-CHANNELIZATION TECHNIQUES FOR DOWNLINK MOBILE WiMAX IEEE 802.16e PERFORMANCE

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Abstract

Broadband Wireless Access (BWA) is a technology which advantages are wide coverage services, large capacities and good quality service. Nowadays, BWA technology has various kinds of superior products and one of them is Worldwide Interoperability for Microwave Access (WiMAX). WiMAX has evolved from fixed WiMAX to mobile WiMAX.

Mobile WiMAX, which standard is IEEE 802.16e, is not only use for mobile user but also Non Line of Sight (NLOS) channel. The reason is some of innovative technology applications have supported IEEE 802.16e in order to cope the problem. One of the innovative technologies is Sub-Channelization. Sub-Channelization used in mobile WiMAX is Full Usage Subcarrier (FUSC) and Partial Usage Subcarrier (PUSC).

This paper analyzes the comparison performance between sub-channelization technique FUSC and PUSC in downlink mobile WiMAX. Simulation is done in different number of user and velocity of user. The result of simulation shows that system with different user velocity (0, 3, 30 and 120 km/hour), the faster user, the higher error bit value. FUSC give BER repair ± 50% for same Eb/No value. Meanwhile, system with different number of user (1, 4, 16 and 32 users), FUSC can give performance correction for ± 0.37 dB. Because, FUSC process is subcarrier permutation while PUSC process are cluster permutation and subcarrier permutation. Thus, process period of PUSC is longer than FUSCs. Hence, Eb/No of PUSC is greater than FUSC. In conclusion, FUSC give better performance for different number of user and user velocity.

Key Words: Mobile WiMAX, Sub-Channelization, FUSC, PUSC, Downlink.

1. Introduction

In recent years, people call for improvement in the service quality of multimedia (voice, video, data, and picture) communication so that there is a technology named Broadband Wireless Access (BWA). BWA comes along with the increasing of broadband access that needs wide bandwidth and large capacity. However, BWA still has problems to solve and one of them is Non Line Of Sight (NLOS) channel condition. Furthermore, NLOS will cause multipath fading that causes great delay spread and Inter Symbol Interference (ISI).

One of BWA's product is Worldwide Interoperability for Microwave Access (WiMAX). Accomplishing the need of telecommunication, WiMAX has evolved from fixed WiMAX to mobile WiMAX. Mobile WiMAX, which standard is IEEE 802.16e, is suitable for NLOS channel condition. It is because mobile WiMAX is supported by some innovative technologies, for instance OFDM (Orthogonal Frequency Division Multiplexing) and sub-channelization. Sub-channelization used in mobile WiMAX are Full Usage of Subcarrier (FUSC) and Partial Usage of Subcarrier (PUSC).

The use of sub-channelization has different effect on the performance of mobile WiMAX because both of FUSC and PUSC have different process. Even though these are a subcarrier permutation method that subcarriers are distributed throughout the available spectrum, these still have attraction to be observed. Despite this reason, this paper will analyze how these sub-channelization affect the performance if there are different number of user and user velocity. The process will be done based on standard that mobile WiMAX has, IEEE 802.16e. The simulation is done in different user number (single user and multi user) and velocity (fixed and mobile).

2. System Description

Mobile WiMAX, a Broadband Wireless Access product, is a development technology from fixed WiMAX. Its standard is IEEE 802.16e that supports high-speed data access, security, service quality and mobility. Solving NLOS problem, mobile WiMAX is equipped with OFDM technology, sub-channelization, directional antenna, transceiver diversity, adaptive modulation, error channel correction, and power control [2]. Besides, it supports not only channel bandwidth 1.25 Mhz to 20 MHz but also 2048 number of subcarrier.

OFDM is designed to overcome NLOS problem because it works on multicarrier transmission concept. This concept will divide data stream into some parallel sub streams. Then, it will be placed at subcarrier frequency that is closed and orthogonal. After that, it is transmitted serially. This concept also can change the speed of data, from high speed data to low speed data. The reason is subcarrier period will be greater to overcome delay spread that is happened due to NLOS channel condition.

Transmitting many users, mobile WiMAX uses OFDMA in physical layer. OFDMA is created by using multiple access scheme to transmit many data users both downlink sub-channel and uplink sub-channel. In a simple, OFDMA will divide a group of subcarrier to be allocated for many users. In the process of OFDMA, it adds cyclic prefix to give immunity caused by multipath and to avoid error synchronization.

Besides, OFDMA has sub-channelization. It is defined as a group of subcarrier allocated in frequency spectrum. A sub-channel is consisted of data subcarrier, pilot subcarrier and null subcarrier. A sub-channel is consisted of data subcarrier, pilot subcarrier and null subcarrier.

The distribution of subcarriers in a sub-channel is called subcarrier permutation. These subcarriers have not to be adjacent or even it can be sprout in all frequency bands. That is why there are two methods of subcarrier permutation; diversity subcarrier permutation and adjacent subcarrier permutation.

Diversity subcarrier permutation distributes subcarriers randomly, for instance, Full Usage Subcarrier (FUSC) and Partial Usage Subcarrier (PUSC). Its advantages are frequency diversity and inter cell interference. Besides, it can reduce the use of same subcarrier in a sector or cell. In other hand, it is difficult to estimate channel. Meanwhile, adjacent subcarrier permutation is a group of contiguous subcarrier. The example is Adaptive Modulation and Coding (AMC). This method needs the best condition of bandwidth but it is easy to estimate channel because of adjacent subcarrier.

2.1 Downlink FUSC

Full Usage Subcarrier (FUSC) uses all data subcarrier to create some sub-channels. They are allocated for a sector or a cell to obtain diversity. Limited overhead (pilot and guard subcarrier) in FUSC makes the number of transmitted data subcarrier is greater than PUSC. In other hand, the transmitted data will be useless, if not all subcarriers are used. A slot of FUSC consists of a symbol of FUSC.

There are two kinds of pilot in FUSC; constant set pilot and variable set pilot. The difference of these is in the index of pilot subcarrier. Constant set pilot has permanent index while variable set pilot has random index. Variable set pilot is possible to predict channel response precisely, especially in great delay spread channel (small coherent bandwidth)[7].

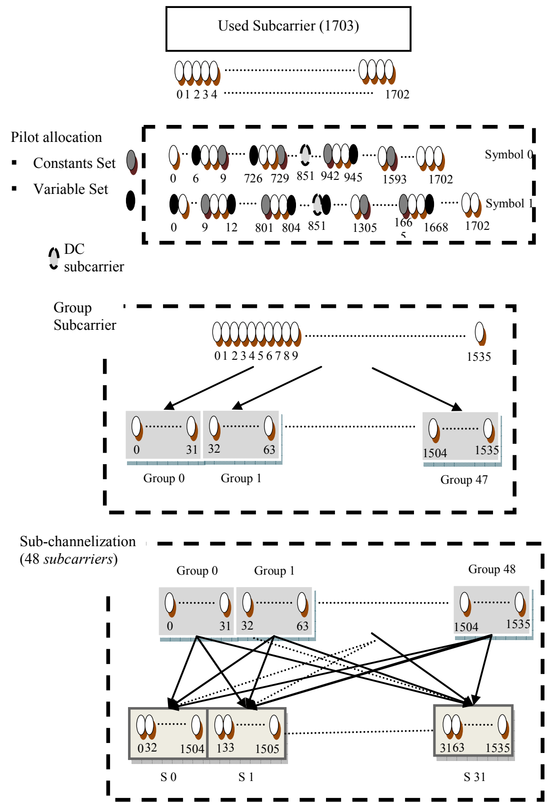

Figure 1. FUSC Permutation Process

In FUSC process, first, pilot subcarriers (constant set and variable set) are allocated using equation below:

$$\text{Pilot Locations} = \text{Variabel sets}\ \# + (6 \times (\text{FUSC symbol number}\ mod\ 2))\ [6] \quad (1)$$

Then, adjacent subcarriers are formed to be some groups and are allocated into a sub-channel. The number of sub-channel is as same as the number of subcarriers in a group. After that, remaining data subcarriers that are allocated are based on the equation below:

$$S(k,s) = N_{cn}.\eta_k + \{P_s(\eta_k\ mod\ N_{cn}) + DL\_PBase\}\ mod\ N_{cn} \quad (2)$$

Where,

S(k,s) the index of subcarrier k among all available data subcarriers. With 2048-FFT, index of subcarrier ranges from 0-1535.

s the index number of a sub-channel in a group, from the set [0...Nsubchannels-1] i.e., with 2048-FFT, Nsubchannels ranges from 0-32.

k the subcarrier-in-sub-channel index from the set [0...Nsubcarrier - 1]. It ranges from 0 - 47.

N_{cn} The number of sub-channel.

η_k $(k + 13s) \bmod N_{subcarrier}$.

DL PBase *Range* 0 – 31.

$P_s[.]$ is the series obtained by rotating basic permutation sequence cyclically to the left s times (Table-311 [3]). Ps[.]= {3, 18, 2, 8, 16, 10, 11, 15, 26, 22, 6, 9, 27, 20, 25, 1, 29, 7, 21, 5, 28, 31, 23, 17, 4, 24, 0, 13, 12, 19, 14, 30}.

FUSC permutation scheme has different parameter for each FFT size. It is shown from table below:

Table 1 FUSC Permutation Scheme Permutasi

FFT	128	256	512	1024	2048
Data subcarriers used	96	192	384	768	1536
• *Subcarriers per subchannels*	48	N/A	48	48	48
• *Number of subchannels*	2	N/A	8	16	32
Pilot Subcarriers in constant set	1	8	6	11	24
Pilot Subcarriers in variable set	9	N/A	36	71	142
Left-guard subcarriers	11	28	43	87	173
Right-guard subcarriers	10	27	42	86	172
DC subcarrier	1	1	1	1	1

2.2 Downlink PUSC

In Partial Usage Subcarrier (PUSC), some of data subcarriers are used to form sub-channel to obtain diversity. There is only one group that uses in one cell or sector depend on traffic condition in order to reduce interference. A slot of PUSC consists of two OFDMA symbol (odd and even symbol). The process of PUSC is divided into some steps, they are:

1. Outer Permutation
   It consists of physical cluster formation and logical cluster formation.
2. Inner Permutation
   A process of allocating subcarriers has group formation and sub-channelization.

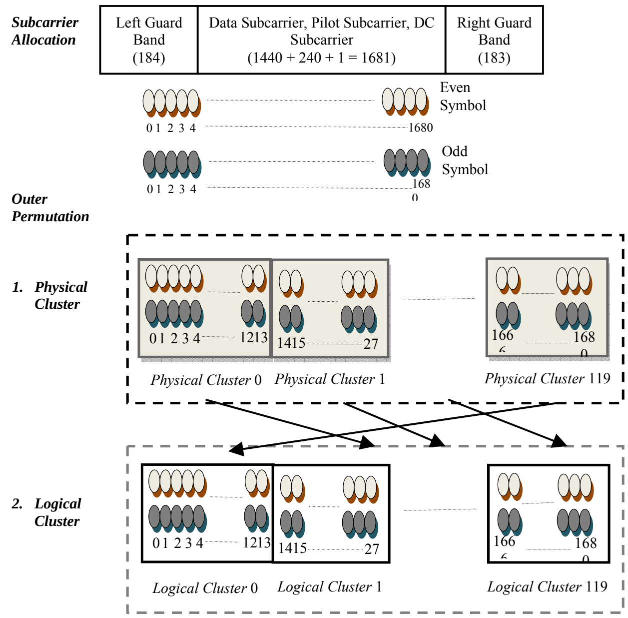

Figure 2. Outer Permutation

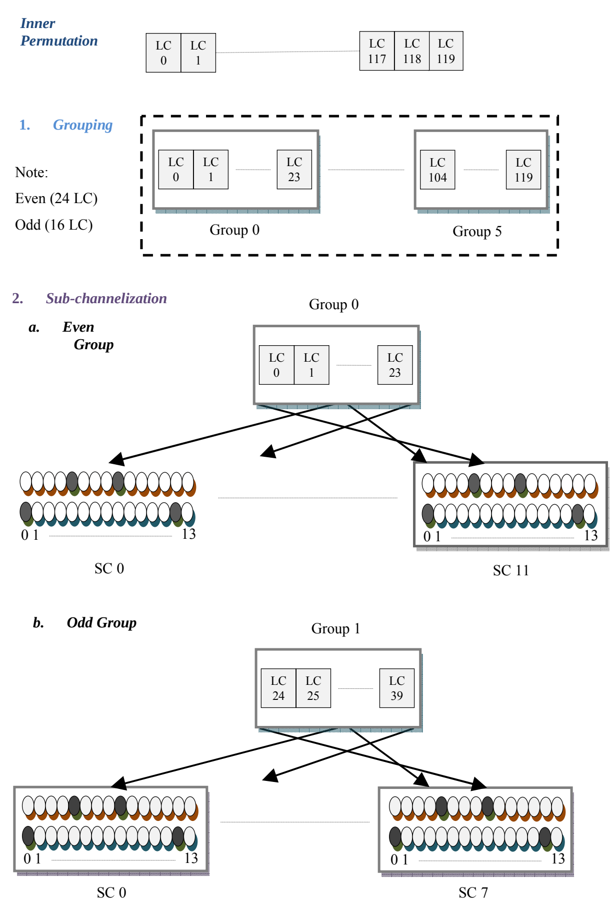

Figure 3. Inner Permutation

The process starts with physical cluster that is a group of fourteen adjacent subcarriers. Then, logical cluster is created by renumbering physical cluster. Logical cluster is done by equation 3.

$$Logical\ cluster = Renumbering\ Sequence\ (PC) + 13.DL\_PBase[6] \quad (3)$$

After that, logical clusters are formed by six groups that have even and odd group (group 0 to group 5). The even group consists twenty-four clusters while the odd group consist sixteen clusters. The even group will create twelve sub-channels and the odd group will create eight sub-channels. Pilot subcarriers position spread out for odd and even OFDM symbol. The equation for inner permutation shows below:

$$S(k,s) = N_{cn}.\eta_k + \{P_s(\eta_k\ mod\ N_{cn}) + DL\_PBase\}\ mod\ N_{cn} \quad (4)$$

Where,

S (k,s) — The index of subcarrier k within a group (i.e., with 2048-FFT, in group `0', it ranges from (0-287).

s — The index number of a subchannel in a group, from the set [0 - Nsubchannels-1] (i.e., with 2048-FFT, Nsubchannels for even and odd groups are 12 and 8 respectively).

k — The subcarrier in sub-channel index from the set. [0 - Nsubcarrier-1]

N_{cn} — The number of sub-channel for odd group is eight and for even group is twelve.

η_k — (k + 13s) mod $N_{subcarrier}$.

DL PermBase — *Range* 0 – 31.

P_s[.] — The series obtained by rotating basic permutation sequence cyclically to the left s times Ps[:] = {6; 9; 4; 8; 10; 11; 5; 2; 7; 3; 1; 0} and {7; 4; 0; 2; 1; 5; 3; 6} for even and odd groups respectively.

The allocated subcarrier should be appropriate with the PUSC parameter below:

Table 2. PUSC Permutation Scheme Parameter

FFT	128	512	1024	2048
Data Subcarriers used	72	360	720	1440
• *Data Subcarriers per subchannels per symbol*	12	12	12	12
• *Number of subchannels*	3	15	30	60
Pilot Subcarriers	12	60	120	240
• *Pilot Subcarriers per subchannels per symbol*	2	2	2	2
Left-guard subcarriers	22	46	32	184
Right-guard subcarriers	21	45	91	183

3. Model System

3.1 Transceiver System

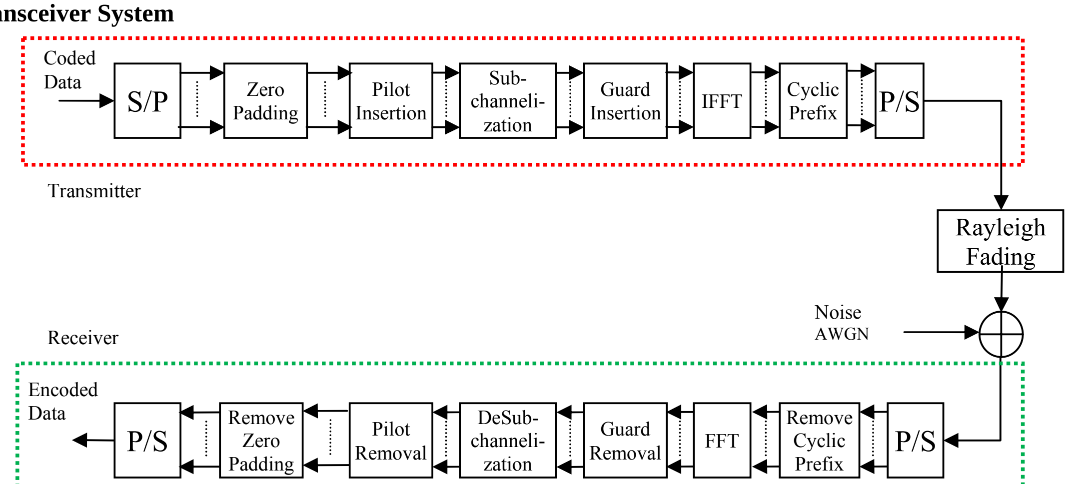

Figure 5. Transceiver OFDMA Diagram

Figure 6. Channel Coding Process

The simulation uses same method in number of bit, bit rate code, modulation type and channel condition. It was done to make simulation easier. The used numbers of bit are 1024. The parameters below used in the simulation according to IEEE 802.16e standard.

- Frequency : 3,5 GHz
- Channel Bandwidth : 20 MHz
- FFT Size : 2048
- Sampling Factor : 8/7
- Sampling Frequency : 22,8 MHz
- Spacing Subcarrier : 11,16 KHz
- Used Symbol Period : 89,6 µs
- Cyclic Prefix Ratio : 1/8
- Cyclic Prefix Period : 11,2 µs
- Periode simbol OFDMA : 100,8 µs

3.2 Transmission Channel

Channel model used in simulation are Rayleigh distributed multipath fading and AWGN (Additive White Gaussian Noise) channel. The chosen Jakes Model uses six delay taps and relative path power.

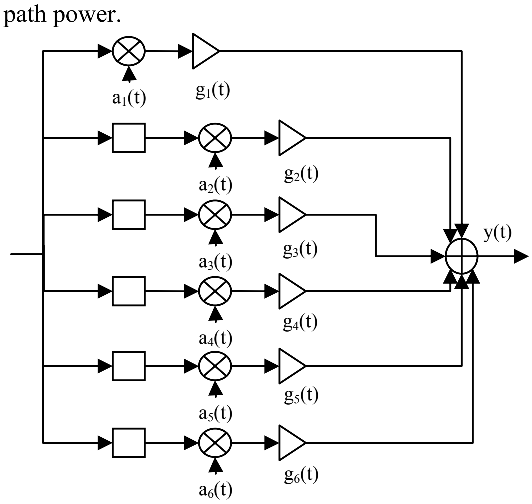

Figure 7. Multipath Fading Channel in Six-Path Delay

Where,

$s(t)$	= transmitted signal
τ_i	= multipath delay
$a_i(t)$	= Rayleigh variable coefisien
$g_i(t)$	= given gain
$y(t)$	= summary of received signal
I	= 1,2,3,...,6

Table 3. Multipath Delay Channel

Taps	*#1*	*#2*	*#3*	*#4*	*#5*	*#6*
Delay (ns)	*0*	*310*	*710*	*1090*	*1730*	*2150*
Relative path power (dB)	*0*	*-1*	*-9*	*-10*	*-15*	*-20*

4. Simulation Results

4.1 Single User

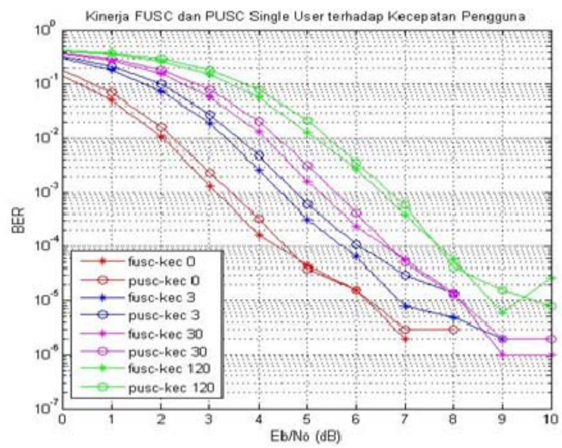

Figure 8. Single User Comparison between FUSC and PUSC

Table 4. Single User FUSC and PUSC Performance

Velocity	FUSC		PUSC	
	BER	Eb/No (dB)	BER	Eb/No (dB)
0 km/hour	10^{-5}	6.24	10^{-5}	6.26
3 km/hour	10^{-4}	5.75	10^{-4}	6.07
30 km/hour	10^{-5}	8.12	10^{-5}	8.13
120 km/hour	10^{-5}	8.75	10^{-5}	9.65

Figure 8 shows that the faster user moves, the greater Eb/No is needed. Besides, FUSC has better BER than PUSCs; it shows when these Eb/No are less than 4 dB. Table 4 shows that the faster user moves, the greater BER value is. It happens because mobile user will make mean time alteration in radio mobile channel that causes Doppler spread. This condition appears because there is a phenomenon of user frequency shift. The faster user move, the higher Doppler shift is. Furthermore, there will be an Inter Carrier Interference (ICI) effect. ICI happens in non- linear channel condition that will influence symbol detection process and received power in antenna.

4.2 Four Users System

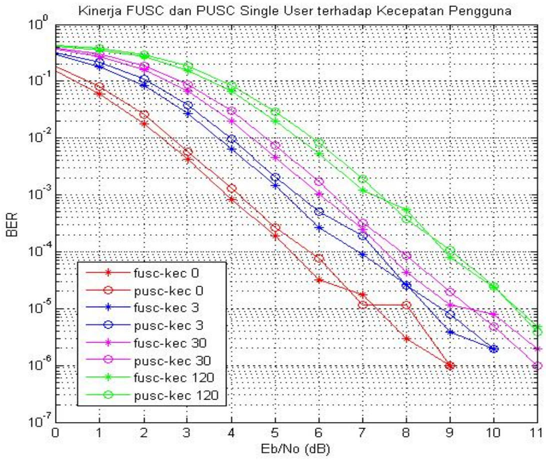

Figure 9. Four Users Comparison between FUSC and PUSC

Table 5. Four Users FUSC and PUSC Performance

Velocity	FUSC		PUSC	
	BER	Eb/No (dB)	BER	Eb/No (dB)
0 km/hour	10^{-6}	9	10^{-6}	9
3 km/hour	10^{-5}	8.5	10^{-5}	8.75
30 km/hour	10^{-6}	12	10^{-6}	11
120 km/hour	10^{-5}	10.51	10^{-5}	10.49

Figure 9 shows the faster users move, the greater Eb/No is. Mobile users will cause the alteration of mobile radio channel mean time so that Doppler spread appears. The faster users move, the higher Doppler shift happens. That is why signal will have distortion. Besides, the faster user move, the greater BER value is.

Table 5 shows an insignificantly differenced performance of FUSC and PUSC with same BER and Eb/No. They have almost same use of power signal. However, PUSC has better performance than FUSC when user moves for 30 km/hour. It happens because PUSC is more stable than FUSC confront to random channel. PUSC does twice as many as FUSC to maintain its system stability.

4.3 Sixteen Users System

Table 6. Sixteen Users FUSC and PUSC Performance

Kecepatan	FUSC		PUSC	
	BER	Eb/No (dB)	BER	Eb/No (dB)
0 km/jam	10^{-4}	7,26	10^{-4}	7,58
3 km/jam	10^{-6}	8,95	10^{-6}	9,95
30 km/jam	10^{-5}	9	10^{-5}	9,5
120 km/jam	10^{-4}	8,39	10^{-4}	8,76

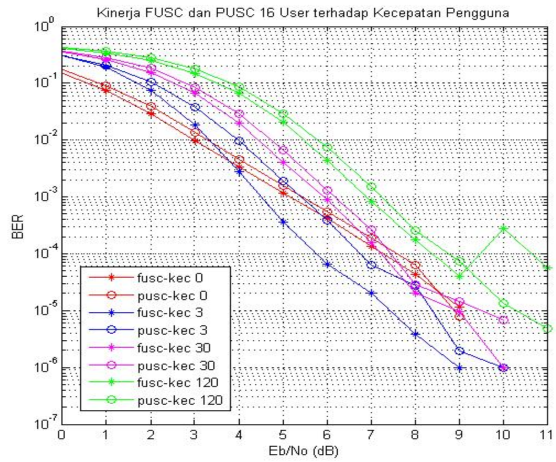

Figure 10. Sixteen Users Comparison between FUSC and PUSC

Table 6 and Figure 10 show fix users need greater bit energy to overcome random channel. It also because noise for mobile user is greater than fix users so that Eb/No for mobile user is smaller. Eb/No will be greater when users move faster. Moreover, figure 10 shows that system start to be unstable. It happens because subcarrier allocation is less along with the increasing of number of user. Hence, user subcarrier interference is easier to appear.

4.4 Thirty-two Users System

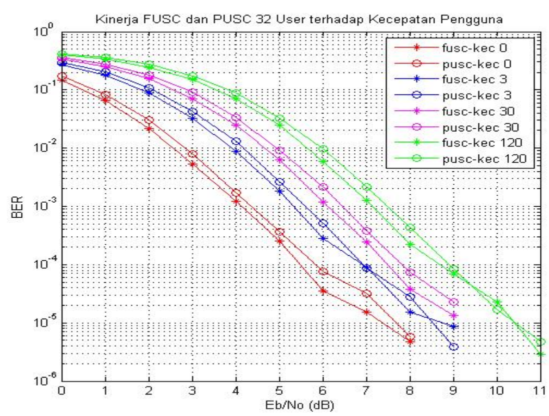

Figure 11. Thirty Users Comparison between FUSC and PUSC

Table 7. Thirty-two Users FUSC and PUSC Performance

Kecepatan	FUSC		PUSC	
	BER	Eb/No (dB)	BER	Eb/No (dB)
0 km/jam	10^{-5}	7,35	10^{-5}	7,7
3 km/jam	10^{-5}	8,5	10^{-5}	8,76
30 km/jam	10^{-4}	7,46	10^{-4}	7,8
120 km/jam	10^{-5}	10,4	10^{-5}	10,42

Figure 11 and Table 7 shows the needed Eb/No will be greater if users move faster. The system seems unstable because allocated subcarrier is smaller. It will lead to user-subcarrier-interference appearance. Furthermore, more error will appear and it will be difficult to be detected and to be corrected in receiver.

5. Conclusion

1. Single user system, FUSC has better performance than PUSC. It shows in 4 dB Eb/No for fix user, FUSC BER is 1.67 10^{-4} while PUSCs is 3.33 10^{-4}.
2. Four users system, FUSC performance is better than PUSCs. For instance, when Eb/No is less than 7 dB, 3 km/hour user BER for FUSC is 8.79 10^{-5} while PUSCs is 1.88 10^{-4}.
3. Sixteen users system, FUSC Eb/No is better than FUSCs. It shows that Eb/No for FUSC fixed user and mobile user are 7.26 dB, 8.95 dB, 9 dB dan 8.39 dB while PUSCs are 7.58 dB, 9.95 dB, 9.5 dB dan 8.76 dB.
4. Thirty-two users system, FUSC is better than PUSC because FUSC need smaller signal power than PUSCs. For instance, BER value is 10^{-6} and FUSC's signal power is 8.95 dB while PUSCs is 9.95 dB.

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