Performance Analysis of Modulation Technic of CCK- OFDM on Wireless Communication

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***Abstract*— The increased use of data communications and improved infrastructure in the area of urban / metropolitan and the high user mobility are some factors that produce signal propagation problems. These problems affect the quality of communication services.**

The application of coherent channel communication system , on the transmitting and receiving devices, is able to maintain the service quality by means of channel estimation . The application of the estimated channel is an ideal solution; however, the implementation is very difficult due to the sophisticated system when it is applied to fast fading channels. OFDM modulation supports broadband communications with high data rate and handles frequency selective fading, but it is not able to overcome the problems of fast fading conditions. Therefore to handle this condition, this requires a particular multicarrier technique.

The Non-coherent communication system on the channel could become one of the alternative solutions, because it did not require carrier recovery at the receiver. This technique was simpler than the coherent channel communication systems because this CCK modulation technique applied reliable non-coherent communication systems to overcome the fast fading conditions. This modulation implemented DQPSK, a differential modulator on the transmitter and a Modified-FWT with channel match filter and correlator functioning as a rake receiver at the receiver system so that this system was able to overcome the effect of multipath channels.

This research showed that the integration of CCK and OFDM to overcome the multipath channels and the high user mobility had improved the performance shown by the curves of BER for Eb / No.

Keywords—urban/metropolitan; multipath; fast fading; high data rate; BER; Eb/No; OFDM; CCK

I. INTRODUCTION

Utilization of broadband communications has increased over the years as well the development of environmental infrastructure. Signal propagation in the urban/metropolitan area lead to many indirect signals received by the user equipment with a variety of signal power and time delay varies with propagation problems that arise due to user mobility. This mobility cause fast fading and it will be difficult to control.

Through the application of coherent communication techniques channels, Channel State Information at Transmitter or/and receiver, the sending and receiving equipment can maintain the quality of service with a well-defined channel estimation is the ideal solution. But it will be very difficult to realize given the complexity of the system is so complex. Broadband communications with high data rates supported by OFDM modulation, with its estimated channels, can only be overcame frequency selective fading conditions are not sufficient to cope with fast fading channel. Therefore, non-coherent communication system on the channel could be an alternative solution.

In previous research, Complementary Code Keying modulation system (CCK) is one of various of technique M-Ary Orthogonal Keying had been developed[3], which later built by Intersil and Lucent Technology[2] and in-reassemble on research in 2003 - [4]. In the research, mentioned that there is an increase in system performance against multipath channel conditions especially in indoor conditions. This modulation is applied on WLAN IEEE 802.11b[2].

CCK has an advantage in overcoming multipath channel and user movement with non-coherent communication and differential modulator implemented implemented. While OFDM with its orthogonality among subcarrier has an advantage in overcoming the frequency selective fading and other advantages are its efficiency in provisioning of channel to deliver broadband. By combining these two techniques, the channel conditions described above, can be overcame and increased performance that measured by BER against Eb/No.

In this paper emphasizes on the CCK blocks include DQPSK as mapper, binary complementary code, polyphase complementary code, differential modulator, modified-FWT, demapping symbol to bit stream, and OFDM itself.

II. KNOWLEDGE

A. CCK

CCK (Complementary Code Keying) is a variation of M-Ary Orthogonal Keying which uses I/Q modulation architecture with complex symbol structure this allows for multi-channel operation[4]. CCK uses DQPSK as non-coherent communication modulations at transmitter and receiver, Binary Compelementary Code and Polyphase Complementary Code produce Codeword Complex as symbol which is transmitted from differential modulator, and uses Rake model at its receiver.

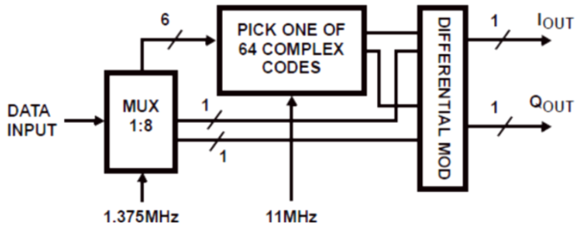


Figure 1. Transmitter Block Diagram of CCK [6]

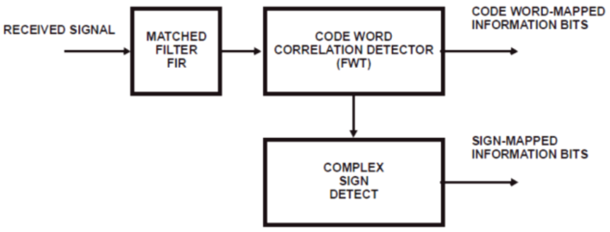


Figure 2. Receiver Block Diagram of CCK [6]

B. DQPSK

DQPSK is widely used in non-coherent communication which simplify receiver in signal recovery[5].

Differential Quadrature Phase Shift Keying (DQPSK) is one type of digital modulation of M-Ary Phase Shift Keying (M-Ary PSK). The resulting symbol is the result of phase differentiation between the M bits. That symbols are sent by the transition state recovery on the receiver.

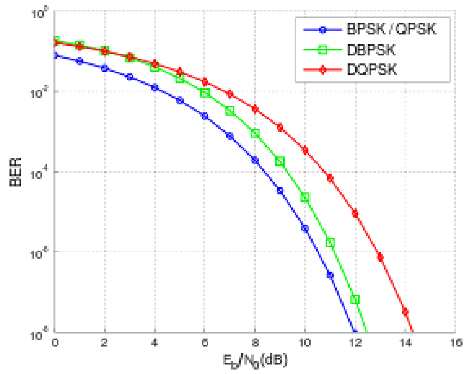


Figure 3. Kurva Perbandingan Performansi BER vs EbNo BPSK/QPSK, DBPSK dan DQPSK pada Kanal AWGN

One of disadvantage in non-coherent communication is achieving BER are not as good as coherent communication. This can be seen in figure 1 that larger Eb/No, DQPSK performance of approximately 2.3dB worse than QPSK[5].

C. Binary Complementary Code

Complementary code basically is adopted by M.J.E Golay for infrared multislit spectrometry. The properties of codes are used for radar and communication[2]. More description available in-[1]. Following are the recursive rule of Golay Code,

$$A_n = A_{n-1}\,B_{n-1} \qquad (1)$$

$$B_n = A_{n-1}\,B'_{n-1} \qquad (2)$$

$$B' = -B \qquad (3)$$

D. Polyphase Complementary Code

Polyphase complementary code uses four different phase defined by complex numbers {1, -1, j, -j}. These codes are generated through a combination of matrix subsets formed by N (length of the codeword), the next step is determine the log2N subsets of mutually orthogonal. Subsets are formed from a single element even order, 2 pairs of elements, 4 pairs of elements, and so on[7].

E. OFDM

OFDM is a special form of multicarrier modulation (MCM), where a single data stream is transmitted over a number of lower rate subcarriers where the subcarriers are orthogonal each other [8].

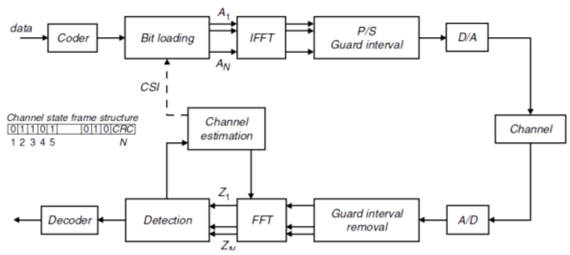


Figure 4. Transmission System Block Diagram of OFDM [9]

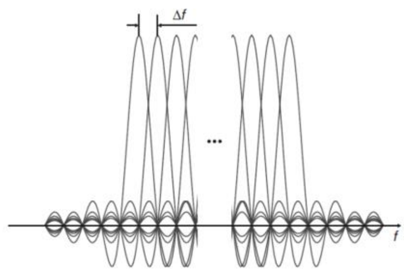
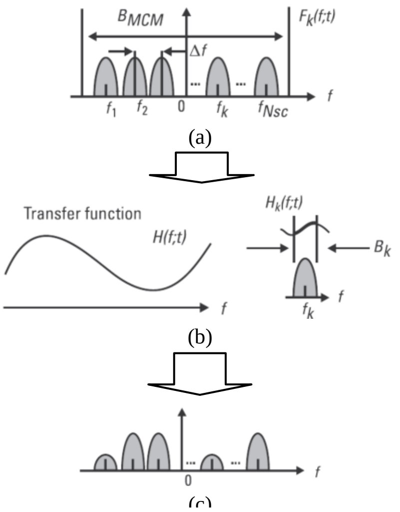


Figure 5. Representation of OFDM Subcarriers [9]

The advantages of OFDM is its robustness combat frequency selective fading channel. Because it uses a lot of subcarrier so the frequency selective fading channel will be felt as flat fading on each subcarrier. It must be easier to control.



CFigure 6. (a) Frequency Spectra of Transmitted Signal; (b) Channel; and (c) Frequency Spectra of Received Signal [8]

Multipath Channel

Multipath fading is due to multipath reflections of a transmitted wave by local scatterers such as houses, buildings, and man-made structures, or natural objects such as forest surrounding a mobile unit [8].

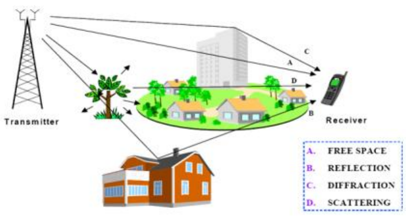


Figure 7. Ilustration of Multipath Channel

For instance, when no line-of-sight component is available in a channel, the data transmission rate is very high, and the receiver is installed in a high-speed cruising vehicle, the channel will be ‘‘a frequency selective fast Rayleigh fading channel,’’ [8].

III. DESIGN IF THE SYSTEM

Each excellences of CCK and OFDM modulation techniques are combined to produce a broadband wireless communication system that are reliable against multipath interference channel with high mobility.

Transmitter block of complementary code that are designed in this research consists of the symbols generated by DQPSK modulator, Complementary Binary Code (applied from Golay's Code), polyphase Complementary Code which then produces a row of Complex Codeword. Not quite up here, a row of Complex Codeword produced further processed by differential modulator which is then combined with OFDM technique using block Inverse Fast Fourier Transform (IFFT).

Meanwhile, in frequency domain receiver block of the received signal is converted into time domain by a block of Fast Fourier Transform (FFT), and then through a channel match filter and modified-FWT which acts as a rake receiver, the symbols are de-mapped into a row of information bits.

This system was examined on frequency selective slow and fast Rayleigh fading channel.

A. *Channel Modelling*

Channels are modeled with six-tap that are generated using Jake's model.

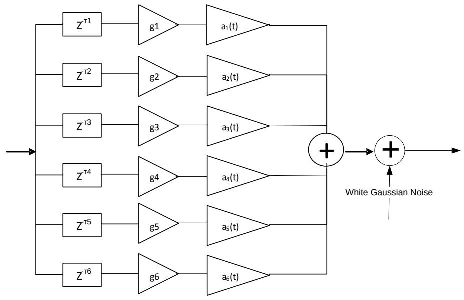


Figure 8. Model Structure of Multipath Channel with AWGN

B. *Code*

Some of the code in CCK is Golay's Code used on binary complementary code, polyphase complementary which then produces codeword complex.

- Binary Complementary Code
  Refer to the rules for generating Golay codeword as shown in (1), (2) and (3), can be described as follows,

Figure 9. Processes of Generating Binary Complementary Code

Based on flow of binary complementary code for the eight sequences (N = 8) are [1 1 1 -1 1 1 -1 1].

- Polyphase Complementary Code
  Length of the codeword that has previously been determined, there are a number of $\log_2 N = \log_2 8 = 3$subsets. So that to generate polyphase needed $1+ \log_2 N = 1+ \log_2 8= 4$ phases which are output from DQPSK modulator (ω_1, ω_2, ω_3 dan ω_4). The flow of generating polyphase complementary code is described as follows,

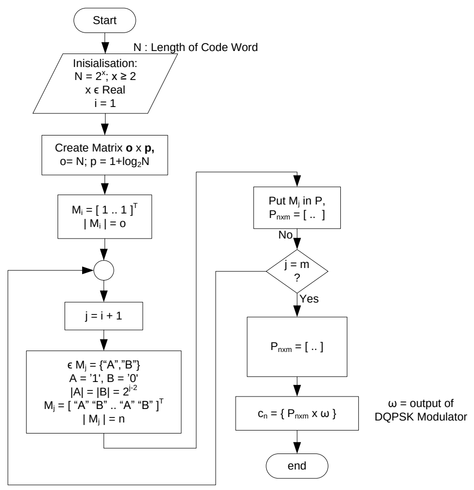


Figure 10. Processes of Generating Polyphase Complementary Code

C. *Transmitter of System*

Transmitter on this system is built by Serial to Parallel, Complex Code, Differential Modulator, IFFT, and Parallel to Serial. The codes that are used in this block are consists of eight sequences code, which are eight sequences of binary complementary code, 4x8 matrix of polyphase and the result next are the eight sequences of complex codeword. Each blocks are integrated as describe in figure below,

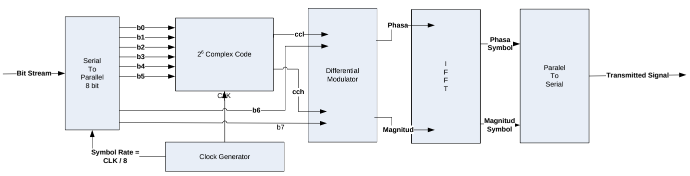


Figure 11. Transmitter Block Diagram of CCK-OFDM

- Complex Codeword
  There are only six of eight bit that is processed in this block. Two other bits are operand at the next block, differential modulator.

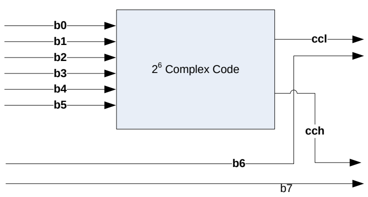


Figure 12. Block Diagram of Complex Code

The six bit are modulated by DQPSK into four symbols, as phase (ω = [ω_1, ω_2, ω_3 and ω_4]). Using the properties of CCK, complex codeword (CW) generated by combining polyphase (PP), phase (ω) and binary complementary code (BC) as describe below,

$$CW = (PP \times \omega)^T . x\ BC \quad (4)$$

$$CW = \{ e^{j(\omega1+\omega2+\omega3+\omega4)}, e^{j(\omega1+\omega3+\omega4)}, e^{j(\omega1+\omega2+\omega4)}, -e^{j(\omega1+\omega4)}, e^{j(\omega1+\omega2+\omega3)}, e^{j(\omega1+\omega3)}, -e^{j(\omega1+\omega2)}, e^{j(\omega1)} \} \quad (5)$$

- Differential Modulator
  The outputs of complex codeword are divided into two sides, hi-complex codeword and lo-complex codeword, that are four sequences at each sides. The two left bits, b_6 and b_7, are operand for these complex codeword on this block .

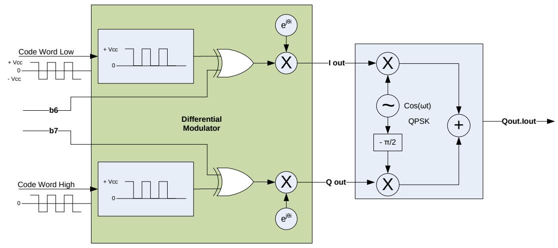


Figure 13. Block Diagram of Differential Modulator

Before all symbols are processed in this block, they need to be normalized by their magnitude so that can be delivered to x-or logic gate as shown in figure 13 above. Actually the magnitude and phase of symbols sequence are also separated in this block. It means that every processes in transmitter block has output twice longer than input because of this separation.

- IFFT
  On this block, 16x1 subcarriers that are orthogonal each others are used. The 16 subcarrier will transform the baseband signal which is still in time domain into frequency domain.

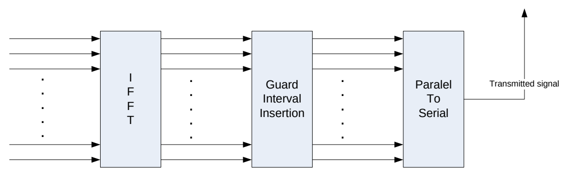


Figure 14. Block Diagram of IFFT 16x1

In this, OFDM, block guard interval is inserted to reduce ISI (Intersymbol Interference).

D. *Receiver of System*

Receiver on this system is built by Serial to Parallel, FFT, Channel Matched Filter, Codeword Corelation Detector, Complex Detector, and Demapper. Binary complementary code and polyphase complementary code are still used in this part, especially in codeword corelation detector and complex detector.

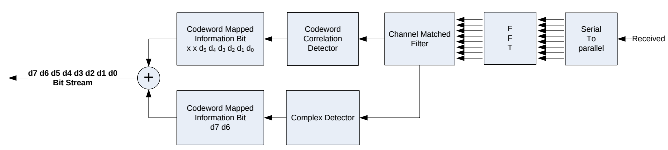


Figure 15. Receiver Block Diagram of CCK-OFDM

- FFT
  Signal is processed into parallel 16 bit. in this block the guard interval is deleted and then processed by

FFT. In FFT 16x1, The signal is transformed into time domain.

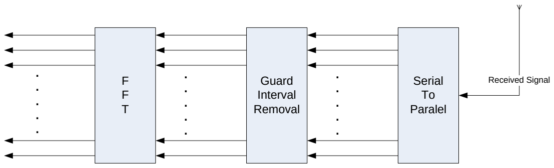


Figure 16. Block Diagram of IFFT 16x1

By the sixteen subcarriers, the influences of channel, frequency selective fading, are reduced so the baseband signal can be processed by the next block.

- Channel Match Filter
  Channel match filter is used to reduce intercarrier interference (ICI) by adopted modified-Fast Walsh Transform that is described in [10].

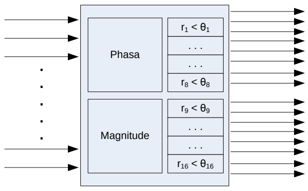


Figure 17. Block Diagram of Channel Matched Filter

Output from this block are also the indentification of magnitude and phase symbol.

- Codeword Correlator Detector
  The magnitude and phase symbol from Channel Matched Filter are cross correlated by Complementary Code Keying. From the results of cross-correlation is taken codeword with the highest correlation values to be mapped into bits of information. The table below is the example of processes in this block,

TABLE 1. Example of Processes in Codeword Correlator Detector

Selected ComplexCode	θ_i	r ∡ θ	Normalized Magnitude
1	0	1 ∡ 0	1
-j	$-\pi/2$	1 ∡ $-\pi/2$	1
-j	$-\pi/2$	1 ∡ $-\pi/2$	1
1	π	-1 ∡ π	0
-1	0	-1 ∡ 0	0
j	$-\pi/2$	-1 ∡ -$\pi/2$	0
-j	$-\pi/2$	1 ∡ -$\pi/2$	1
1	π	-1 ∡ π	0

- Complex Detector
  At the previous step, the phase (θ_i) of symbol is resulted. In this block, that phase (θ_i) is broke down into ω_1, ω_2, ω_3 and ω_4 using polyphase complementary code and magnitude is normalized by binary complementary code.

- Demapper

This is the end of process. Phase values are known and normalized magnitude values can also be known. The next stage is to map these values into a row of bits of information. Where the results of the mapping phase will result in a row of bits [0, 0, d5, d4, d3, d2, d1, d0], and the mapping of the normalized magnitude is a bit d6 and d7.

- Demapper from Magnitude Symbol
  This process is described by example that describe in table below,

TABLE 2. Example of Processes in Demapper from Phase Symbol

θ_i		$\Sigma\varphi_i$	φ_i			
			φ_1	φ_2	φ_3	φ_4
θ_1	0	$\omega_1+\omega_2+\omega_3+\omega_4$	π	$\pi/2$	$\pi/2$	0
θ_2	$-\pi/2$	$\omega_1+\omega_3+\omega_4$	π	$\pi/2$	$\pi/2$	0
θ_3	$-\pi/2$	$\omega_1+\omega_2+\omega_4$	π	$\pi/2$	$\pi/2$	0
θ_4	π	$\omega_1+\omega_4$	π	$\pi/2$	$\pi/2$	0
θ_5	0	$\omega_1+\omega_2+\omega_3$	π	$\pi/2$	$\pi/2$	0
θ_6	$-\pi/2$	$\omega_1+\omega_3$	π	$\pi/2$	$\pi/2$	0
θ_7	$-\pi/2$	$\omega_1+\omega_2$	π	$\pi/2$	$\pi/2$	0
θ_8	π	ω_1	π	$\pi/2$	$\pi/2$	0

Demapping ω_1, ω_2, ω_3 and ω_4 above are demodulated by DQPSK into a row of bits 0, 0, d5, d4, d3, d2, d1, d0.

- Demapper from Phase Symbol
  This process is described by example that describe in table below,

TABLE 3. Example of Processes in Demapper from Magnitude Symbol

Normalized Magnitude	X-OR	Normalized BCK	Demapping		
1	⊕	1	0	0	d_6
1		1	0		
1		1	0		
0		0	0		
0	⊕	1	1	1	d_7
0		1	1		
1		0	1		
0		1	1		

IV. Examination and Measurement

The system that are already built then examined through the frequency selective slow Rayleigh fading channel and frequency selective fast Rayleigh fading channel.

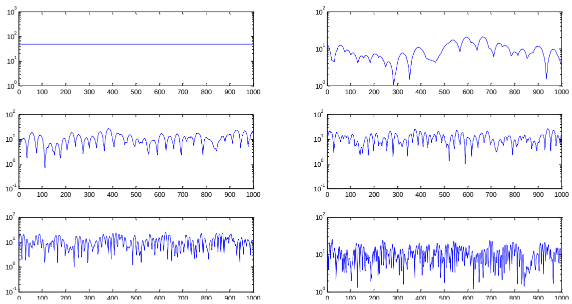
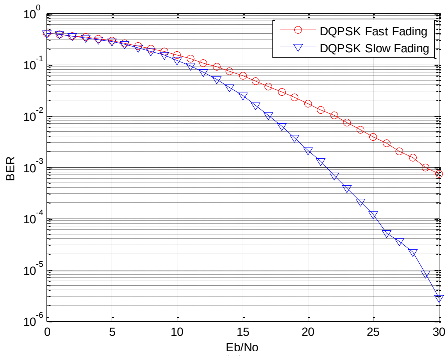
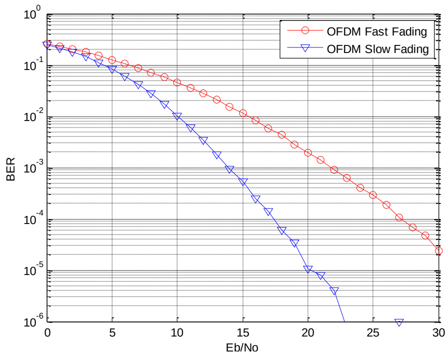


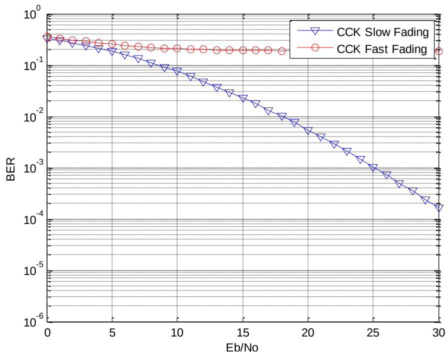
Figure 18. Illustrasion of Frequency Selective Slow and Fast Rayleigh Fading Channel



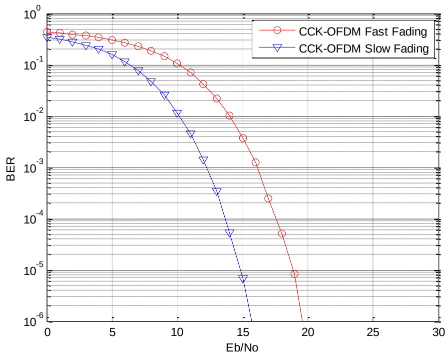
(a)



(b)



(c)



(d)

Figure 18. BER of Systems in a Frequency Selective Slow (*blue*) and Fast (*red*) Rayleigh Fading: (a) DQPSK; (b) OFDM; (c) CCK; (d) CCK-OFDM

Based on system that is examined by simulator in frequency selective slow Rayleigh fading and frequency selective fast Rayleigh fading describe in curves from Figure 19 above.

In DQPSK curve, Eb/No required to achieve BER of 10^{-3} is about 29dB on the condition of fast fading, whereas slow fading conditions, Eb/No required about 21,5dB. In OFDM curve, Eb/No required to achieve BER of 10^{-3} is about 22,2dB on the condition of fast fading, whereas slow fading conditions,Eb/No required approximately 14dB. At CCK, Eb/No required to achieve BER of 10^{-3} is about ~dB on the condition of fast fading, whereas slow fading conditions, the Eb/No required approximately 25dB. In the combination of CCK and OFDM system, Eb/No required to achieve BER of 10^{-3} is about 16dB on the condition of fast fading, whereas slow fading conditions, Eb/No required about 12,5dB. Even through simulation to achieve BER of 10^{-6} by using a combination of CCK-OFDM system Eb/No required for fast fading conditions is 19,7dB.

V. CONCLUSION

It is proved that by combining CCK and OFDM succedded in increasing performance of the system through the parameter BER against Eb/No.

Through the channel conditions, frequency selective slow and fast Rayleigh fading, the combined system CCK and OFDM had a very significant increasing in performance compared to DQPSK, OFDM and CCK itself.

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