LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : PROSIDING

Judul Karya Ilmiah	:	Methods of MIMO Decoders for Very High Throughput WLAN IEEE802.11ac			
Jumlah Penulis	:	3 orang (**Wahyul Amien Syafei**, Maulida, Z., Santoso, I.)			
Status Pengusul	:	Penulis Utama			
Identitas Prosiding	:	a.	Judul Prosiding	:	3rd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE) 2016
		b.	ISBN/ISSN	:	978-1-5090-0890-2
		c.	Thn Terbit, Tempat Pelaks.	:	Oktober 2016, Semarang-Indonesia
		d.	Penerbit/Organiser	:	IEEE Xplore Digital Library
		e.	Alamat Repository/Web	:	https://ieeexplore.ieee.org/document/7892490/
			Alamat Artikel	:	https://doc-pak.undip.ac.id/8005/1/Prosiding_ICITACEE2016.pdf
		f.	Terindeks di (jika ada)	:	ScimagoJR dan Scopus

Kategori Publikasi Makalah : [√] *Prosiding* Forum Ilmiah Internasional
(beri ✓pada kategori yang tepat) [ ] *Prosiding* Forum Ilmiah Nasional

Hasil Penilaian *Peer Review* :

Komponen Yang Dinilai	Nilai Reviewer		Nilai Rata-rata
	Reviewer I	Reviewer II	
a. Kelengkapan unsur isi prosiding (10%)	3,00	3,00	3,00
b. Ruang lingkup dan kedalaman pembahasan (30%)	8,00	8,00	8,00
c. Kecukupan dan kemutahiran data/informasi dan metodologi (30%)	8,00	8,00	8,00
d. Kelengkapan unsur dan kualitas terbitan/prosiding(30%)	9,00	9,00	9,00
Total = (100%)	**28,00**	**28,00**	**28,00**
Nilai Pengusul = (60% x 28,00) = 16,80			

Semarang,

Reviewer 2	Reviewer 1
Dr. Wahyudi, S.T., M.T.	Dr. Iwan Setiawan, ST., MT.
NIP. 196906121994031001	NIP. 197309262000121001
Unit Kerja: Teknik Elektro Fakultas Teknik Universitas Diponegoro	Unit Kerja: Teknik Elektro Fakultas Teknik Universitas Diponegoro

LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : PROSIDING

Judul Karya Ilmiah	:	Methods of MIMO Decoders for Very High Throughput WLAN IEEE802.11ac			
Jumlah Penulis	:	3 orang (**Wahyul Amien Syafei**, Maulida, Z., Santoso, I.)			
Status Pengusul	:	Penulis Utama			
Identitas Prosiding	:	a.	Judul Prosiding	:	3rd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE) 2016
		b.	ISBN/ISSN	:	978-1-5090-0890-2
		c.	Thn Terbit, Tempat Pelaks.	:	Oktober 2016, Semarang-Indonesia
		d.	Penerbit/Organiser	:	IEEE Xplore Digital Library
		e.	Alamat Repository/Web	:	https://ieeexplore.ieee.org/document/7892490/
			Alamat Artikel	:	https://doc-pak.undip.ac.id/8005/1/Prosiding_ICITACEE2016.pdf
		f.	Terindeks di (jika ada)	:	ScimagoJR dan Scopus

Kategori Publikasi Makalah (beri ✓pada kategori yang tepat) :
- [√] *Prosiding* Forum Ilmiah Internasional
- [ ] *Prosiding* Forum Ilmiah Nasional

Hasil Penilaian *Peer Review* :

Komponen Yang Dinilai	Nilai Maksimal Prosiding		Nilai Akhir Yang Diperoleh
	Internasional [30]	Nasional [ ]	
a. Kelengkapan unsur isi prosiding (10%)	3,00		3,00
b. Ruang lingkup dan kedalaman pembahasan (30%)	9,00		8,00
c. Kecukupan dan kemutahiran data/informasi dan metodologi (30%)	9,00		8,00
d. Kelengkapan unsur dan kualitas terbitan/prosiding(30%)	9,00		9,00
Total = (100%)	**30,00**		**28,00**
Nilai Pengusul = (60% x 28,00) = 16,80			

Catatan Penilaian Paper oleh Reviewer :

1. **Kesesuaian dan kelengkapan unsur isi paper:** Isi paper sudah ditulis dengan lengkap dan sesuai kaidah penulisan karya tulis ilmiah. (Nilai 3).

2. **Ruang lingkup dan kedalaman pembahasan:** Pembahasan dilakukan dengan sistematis dan komprehensif. Referensi dari penelitian sebelumnya juga disitasi dengan baik. Dilengkap dengan hasil simulasi dari beberapa metode MIMO decoder. (Nilai 8).

3. **Kecukupan dan kemutakhiran data/informasi dan metodologi:** Metode linier dan non liner untuk melenyapkan interferensi diterapkan pada sistem WLAN IEEE 802.11c terbaru yang merupakan sistem multi antenna dengan throughput sangat tinggi. (Nilai 8**).**

4. **Kelengkapan unsur dan kualitas terbitan:** Isi prosiding lengkap dengan kualitas terbitan berstandar internasional dan diindeks di Scimagojr dan Scopus. Tidak tampak adanya plagiasi dan paper linier dengan bidang ilmu pengusul. (Nilai 9).

Semarang,
Reviewer 2

Dr. Wahyudi, S.T., M.T.
NIP. 196906121994031001
Unit Kerja: Teknik Elektro Fakultas Teknik
Universitas Diponegoro

LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU *PEER REVIEW*
KARYA ILMIAH : PROSIDING

Judul Karya Ilmiah	:	Methods of MIMO Decoders for Very High Throughput WLAN IEEE802.11ac			
Jumlah Penulis	:	3 orang (**Wahyul Amien Syafei**, Maulida, Z., Santoso, I.)			
Status Pengusul	:	Penulis Utama			
Identitas Prosiding	:	a.	Judul Prosiding	:	3rd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE) 2016
		b.	ISBN/ISSN	:	978-1-5090-0890-2
		c.	Thn Terbit, Tempat Pelaks.	:	Oktober 2016, Semarang-Indonesia
		d.	Penerbit/Organiser	:	IEEE Xplore Digital Library
		e.	Alamat Repository/Web	:	https://ieeexplore.ieee.org/document/7892490/
			Alamat Artikel	:	https://doc-pak.undip.ac.id/8005/1/Prosiding_ICITACEE2016.pdf
		f.	Terindeks di (jika ada)	:	ScimagoJR dan Scopus

Kategori Publikasi Makalah : [√] *Prosiding* Forum Ilmiah Internasional
(beri ✓pada kategori yang tepat) [ ] *Prosiding* Forum Ilmiah Nasional

Hasil Penilaian *Peer Review* :

Komponen Yang Dinilai	Nilai Maksimal Prosiding		Nilai Akhir Yang Diperoleh
	Internasional [30]	Nasional [ ]	
a. Kelengkapan unsur isi prosiding (10%)	3,00		3,00
b. Ruang lingkup dan kedalaman pembahasan (30%)	9,00		8,00
c. Kecukupan dan kemutahiran data/informasi dan metodologi (30%)	9,00		8,00
d. Kelengkapan unsur dan kualitas terbitan/prosiding(30%)	9,00		9,00
Total = (100%)	**30,00**		**28,00**
Nilai Pengusul = (60% x 28,00) = 16,80			

Catatan Penilaian Paper oleh Reviewer :

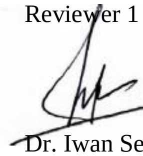
1. **Kesesuaian dan kelengkapan unsur isi paper:** Isi paper sudah lengkap dan sesuai kaidah penulisan karya ilmiah, berisi judul, abstrak, pendahuluan, desain, hasil, kesimpulan dan referensi. (Nilai 3).

2. **Ruang lingkup dan kedalaman pembahasan:** Pembahasan metode dalam paper ini cukup dalam dan runtut, refrensi dari penelitian sebellumnya juga disitasi dengan baik, hasil simulasi beberapa metode juga ditampilkan dan dianalisa. (Nilai 8).

3. **Kecukupan dan kemutakhiran data/informasi dan metodologi:** Beberapa metode untuk melenyapkan interferensi pada sistem multi antenna dianalisa dan dibandingkan. Metode diterapkan pada WLAN yang terbaru IEEE 802.11ac. (Nilai 8)**.**

4. **Kelengkapan unsur dan kualitas terbitan:** Prosiding tersusun dengan lengkap dengan kualitas terbitan berstandar internasional. Terindeks di Scimagojr dan Scopus. Tidak ada unsur plagiasi dan paper adalah bidang ilmu pengusul. (Nilai 9).

Semarang,
Reviewer 1



Dr. Iwan Setiawan, ST., MT.
NIP. 197309262000121001
Unit Kerja: Teknik Elektro Fakultas Teknik
Universitas Diponegoro

Document type
Conference Paper

Source type
Conference Proceedings

ISBN
978-150901434-7

DOI
10.1109/ICITACEE.2016.7892490

View more

Proceedings - 2016 3rd International Conference on Information Technology, Computer, and Electrical Engineering, ICITACEE 2016 • Pages 451 - 454 • 4 April 2017 • Article number 7892490 • 3rd International Conference on Information Technology, Computer, and Electrical Engineering, ICITACEE 2016, Semarang, 19 October 2016 - 21 October 2016, 127215

Methods of MIMO decoders for very high throughput WLAN IEEE802.11ac

Syafei W.A. ✉ , Maulida Z., Santoso I. ✉

Save all to author list

Electrical Engineering Department, Faculty of Engineering, Diponegoro University, Tembalang Campus, Semarang, Indonesia

Abstract

Exponential growing of wireless multimedia communications has forced the IEEE802.11 workgroup to define new standard of WLAN. It is named a Very High Throughput WLAN IEEE 802.11ac which exploits MIMO-OFDM technology to provide up to 6,9Gbps of throughput. MIMO decoder is the vital part of WLAN 802.11ac. It decodes the received signals to get back the transmitted information. There are many methods can be implemented in MIMO Decoder. The linear methods, such as Zero Forcing (ZF)

ISBN : 978-1-5090-1434-7

ICITACEE 2016

THE 3rd INTERNATIONAL CONFERENCE ON INFORMATION TECHNOLOGY, COMPUTER, AND ELECTRICAL ENGINEERING

"GREEN TECHNOLOGY STRENGTHENING IN INFORMATION TECHNOLOGY, ELECTRICAL AND COMPUTER ENGINEERING IMPLEMENTATION"

PROCEEDINGS

SEMARANG, 19TH – 21ST OCTOBER 2016

UNIVERSITAS DIPONEGORO

BECOMES AN EXCELLENT RESEARCH UNIVERSITY

IEEE

CONFERENCE COMMITTEE

General Chair : Abdul Syakur (Universitas Diponegoro)

Co-Chair : R. Rizal Isnanto (Universitas Diponegoro)

Secretary : M. Arfan

Organizing Committee:

Trias Andromeda

Eko Didik Widianto

Teguh Prakoso

Achmad Hidayatno

Ajub Ajulian Zahra

Agung Budi P.

Aghus Sofwan

Yuli Christyono

Sukiswo

Dania Eridani

Rinta Kridalukmana

Steering Committee:

Hermawan (Diponegoro University)

Muhammad Nadzir Marsono (Universiti Teknologi Malaysia)

Riri Fitri Sari (Universitas Indonesia)

Yanuarsyah Haroen (Institut Teknologi Bandung)

Taufik (California Polytechnic State, USA)

Satriyo Dharmanto (IEEE Indonesia Section Chair)

Table of Contents

Electric and Power System

Information and Computer Technologies

Telecommunication and Radio Frequency

Methods of MIMO Decoders for Very High Throughput WLAN IEEE802.11ac

Wahyul Amien Syafei
Electrical Engineering Department
Faculty of Engineering, Diponegoro University
Tembalang Campus, Semarang, Indonesia
wasyafei@undip.ac.id

Zuhrotul Maulida, Imam Santoso
Electrical Engineering Department
Faculty of Engineering Diponegoro University
Tembalang Campus, Semarang, Indonesia
imamstso@undip.ac.id

***Abstract*— Exponential growing of wireless multimedia communications has forced the IEEE802.11 workgroup to define new standard of WLAN. It is named a Very High Throughput WLAN IEEE 802.11ac which exploits MIMO-OFDM technology to provide up to 6,9Gbps of throughput.**

MIMO decoder is the vital part of WLAN 802.11ac. It decodes the received signals to get back the transmitted information. There are many methods can be implemented in MIMO Decoder. The linear methods, such as Zero Forcing (ZF) and Minimum Mean Square Error (MMSE) are simple but low in performance. At the other side, the well-known non-linear method called Maximum Likelihood Detection (MLD) measures the likelihood of the received signal to all symbol candidates. It gives an optimum performance by the cost of very high complexity. Between them, there are some sub-optimal methods, such as K-best, Trellis, and Sphere Detection. These three methods are low in complexity but give performance close to optimum. This paper is adressed to compare the performance and complexity of above methods as MIMO decoders for 8x8 WLAN 802.11ac. Observation is conducted under small room channel model.

***Keywords*—WLAN 802.11ac, MIMO, OFDM, MLD, Trellis, K-best, Sphere, Decoder.**

I. INTRODUCTION

Exponential growing of wireless multimedia communication has sued IEEE-SA (Standard Association) to determine a new WLAN, i.e. 802.11ac. It is able to give maximum 6,9 Gbps of throughput. For providing such very high throughput in very good performance, the 802.11ac exploits MIMO - OFDM (Multiple Input Multiple Output – Orthogonal Frequency Division Multiplexing) technolgy. It combines parallel streaming up to 16 antennas with 160 MHz bandwidth and high-order modulation, i.e. 256-QAM. [1]

MIMO decoder is the vital part of WLAN 802.11ac. It decodes the received signal to get back the transmitted information. There are many methods can be implemented to do this decoding job. Commonly used methods are linear, such as Zero Forcing (ZF) and Minimum Mean Square Error (MMSE). Both of them are simple but low in performance. At the other side, the well-known non-linear method called Maximum Likelihood Detection (MLD) promises optimum performance. It counts all distances of the received signal to symbol candidates. To do this, MLD needs very high complexity of computation which grows exponentially proportional to the number of transmit antennas and the modulation order [2]. In the middle, there are some methods to lower the complexity of MLD while keeping the performance close to optimum. They are called sub-optimum methods. K-Best, Trellis, and Sphere Detection (SD) are members of them.

Performance of MLD based MIMO Decoder for WLAN 802.11n in 20 MHz and 40 Mhz of bandwidth are reported in [3] and [4], respectively. Implementation of sub-optimum methods, i.e. K-best and Trellis in MIMO decoder for WLAN 802.11n system are presented in [5] and [6], respectively. Further, performance comparison of ZF, MMSE, MLD, K-Best, and Trellis methods to cancel the interferences in 2x2 WLAN 802.11ac are observed in [7].

This paper is addressed to explore the performance and complexity of ZF, MMSE, K-Best, Trellis, SD, and MLD as MIMO decoders for 8x8 WLAN 802.11ac. The observation and analyzing is conducted to achieve BER 10^{-6} under small room channel model.

II. MIMO SYSTEM

Received signal in a MIMO system with N transmit and M receive antennas is expressed as:

$$\mathbf{y} = \mathbf{Hx} + \mathbf{n} \tag{1}$$

where $y=[y_1, y_2, ..., y_M]^T$, $\mathbf{H}$ is MIMO channel matrix with size M x N, $\mathbf{x} = [x_1, x_2, ..., x_N]^T$ is the transmitted symbol vector, and $\mathbf{n} = [n_1, n_2, ..., n_M]^T$ is the additive white Gaussian noise.

A. MIMO Decoder for VHT WLAN 802.11ac

In VHT WLAN 802.11ac, MIMO decoder is used to get back the transmitted symbol **x** from the received signal **y.** Most of the WLAN devices implement linear methods in MIMO Decoder, such as ZF and MMSE to decode **y**.

i. Linear Zero Forcing Decoding

In ZF decoding, the received signal is equalized by the inverse of estimated channel matrix, **W.**

Low Latency Network-on-Chip Router Using Static Straight Allocator

Alireza Monemi[*], Chia Yee Ooi[†], Maurizio Palesi[‡] and Muhammad Nadzir Marsono[§]
[*§] Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia
[†] Malaysia-Japan International, Institute of Technology (MJIIT),
Universiti Teknologi Malaysia, 54100, Kuala Lumpur, Malaysia
[§] University of Enna, KORE, Italy
Email: [*]monemi@fkegraduate.utm.my, [†]ooichiayee@fke.utm.my, [‡]maurizio.palesi@unikore.it, [§]nadzir@fke.utm.my

***Abstract*—One clock cycle is the ideal latency for a network-on-chip (NoC) router to pass the received flit in the current cycle to its requested destination output port when there is no contention with other flits. In order to achieve this goal, a newly arrived flit is required to go through all router's pipeline stages to the switch traversal stage. In this paper, we present a low latency synchronized NoC router micro-architecture that achieves single clock cycle latency for packets traveling to the same direction using a static straight VC/SW allocator (SSA). In comparison to existing single clock cycle latency routers which require more complex VC/SW allocator or crossbar switch architectures, our proposed SSA has simpler architecture and works in parallel with the previously proposed baseline VC/SW allocator. The simulation results using six different synthetic traffic patterns shows SSA reduces the communication latency of a 2-cycle latency baseline router by 24% in average.**

I. Introduction

Network-on-Chip (NoC) [1] provides a flexible and extensible inter-core-communication infrastructure for many-core system-on-chips. However, due to multiple number of routers a packet has to traverse between a source and destination cores, as well as each individual router buffering, NoC-based systems can suffer from high inter-core communication latency. Reducing NoC communication latency is important as many-core based applications are highly sensitive to inter-core communication latency. However, designing a low latency NoC router can be a challenge.

Modern NoC routers apply several virtual channels (VCs) on a single physical channel, for multiple proposes such as increasing network throughput, avoiding deadlock in fully adaptive routing [2], isolating resources for different message classes to prevent application level deadlock [3], and improving Quality-of-service (QoS) by generating virtual networks [4]. VC makes the router architecture to become more complex that requires additional VC allocation stage to the existing router pipeline stages.

A conventional VC based NoC router (e.g. [5]) requires four pipeline stages for route computation (RC), virtual channel allocation (VA), switch allocation (SA) and switch traversal (ST) to handle a newly arrived header flit and deliver it to its desired output port. In a conventional router, the result of each pipeline stage is required before the next stage can be executed. Hence, this feature prevents parallel computation and thus results in a 4-cycle latency router architecture as shown in Figure 1(a).

The RC control dependency can be removed using look-ahead route computation (LRC) [8]. LRC computes the output port of a packet, one router in advanced and tags the results to the packet header flit. As shown in Figure 1(b), LRC can be performed in parallel with VA that results in a 3-cycle latency router.

Combining the VC and switch allocation stages relaxes the dependencies between these two stages. In a combined VC/SW allocation (VSA), a VC is allocated only upon successful switch allocation. Compared to conventional NoC routers that allocate VCs before the switch allocation, the combined allocator starts with switch allocation either speculatively [9], [10] or non-speculatively [7]. Speculative combination assumes a successful VC allocation for all non-assigned VC requests and ignores the results of switch allocator in the case of speculation failure. Non-speculative architectures first check the availability of VCs for the requested port and only send the valid requests to the switch allocators. This combination results in a simple VC allocator architecture which can be implemented either using the queues of free VCs for each message classes [10] or by using one stage V:1 arbiter [7], where V is the number of VC per port. LRC and Combined VC/SW allocation results in a two-cycle latency router (Figure 1(c)).

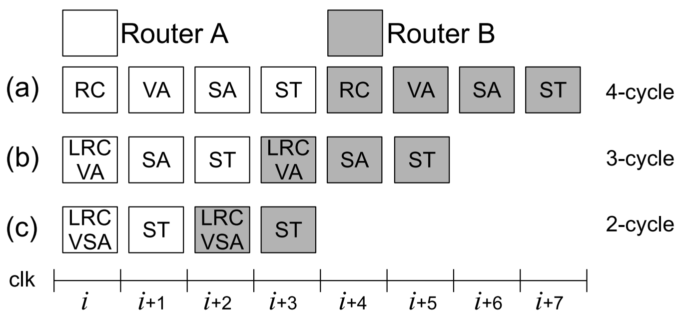


Fig. 1: Pipeline stages of various router architectures. a) Conventional 4-cycle latency router. b) 3-cycle latency look-ahead router. c) 2-cycle latency router using look-ahead routing and combined VC/SW.

One-cycle latency is an ideal latency for a NoC router. It

Brainwave-Controlled Applications with the Emotiv EPOC Using Support Vector Machine

Ha Hoang Kha, Vo Anh Kha, and Dinh Quoc Hung

Ho Chi Minh city University of Technology, VNU-HCM
E-mail: hhkha@hcmut.edu.vn, voanhkha@yahoo.com, hung.dinh@hcmut.edu.vn

***Abstract*—Electroencephalography (EEG) which is the electrical signal recorded by the sensors attached on the human scalp to detect brain activities has been the emerging trends in digital signal processing. As compared to processing other types of digital data such as speech or audio signals, EEG signal processing is more challenging. However, EEG signals have practically found a wide range of important applications. In this paper, we propose a design of a brain-computer interface (BCI) using EEG's P300 component to a control application. First, we use the Emotiv EPOC headset to capture the raw EEG signals. Then, we adopt a classification algorithm by invoking support vector machine along with the selected extracted features to classify the two-class EEG trials (with and without P300 component). The algorithm is developed to help people express their selection of one among four commands. The experimental results are provided evaluate the classification accuracy.**

***Index Terms*—EEG signal processing, P300 brain-waves, brain computer interface, brain-wave-controlled application.**

I. Introduction

Brain-computer interface (BCI) systems are designed for people with difficulties in communication or with severe motor disabilities to express the thoughts by using their bare EEG signals. On top of that, the P300 wave, which is an event-related-potential (ERP) of EEG or say in another way, a specific component of our brain signals, is used in many BCI systems thanks to its clear distinctively observable characteristics among the noisy background of EEG signals. The P300 is an endogenous component of EEG signals elicited by human's brains in the process of decision making. P300's clearly positive voltage peak usually occurs typically approximately at 300 milliseconds after stimulus onset presented by the so-called 'oddball paradigm', in which the low-probability target stimuli are mixed with high-probability non-target ones. Each stimulus is implemented on the computer screen by visual flashing (or intensification) its symbol image. Four images corresponding 4 controlled devices are shown in the screen, on which the subject would focus their eyesight at only one image as their intention, and it is implicitly known as his or her target stimuli, while the other 3 images are the non-target ones. The subject is presented with two categories of stimulus (target and non-target), and he or she is instructed to visually focus on the target stimuli to determine his or her intention.

In 1988 Farwell and Donchin [1] developed a P300-related BCI system called "P300-Speller" as it soon gained the popularity from the EEG community thanks to its wide range of application. In this BCI, a 6-by-6 matrix of 36 letters (24 alphabetical characters and 10 decimal digits) is presented on the computer screen on which the subject focuses their eyesight. During one spelling session, each row or column (which contains 6 letters) is flashed sequentially and randomly in a set of 12 flashes corresponding to 12 rows and columns. Each flash, or saying in another way, each intensification of a row or a column is called a stimulus. A flashing block therefore consists of 12 stimuli. Ideally, there should be only two target stimuli, or two target responses over the total of 12 stimuli. The others are called non-target. Determining which two of the twelve stimuli responses contain P300 component is interestingly enough to determine the letter intended to be spelled out by the subject. However, due to the noisy background of EEG signals which heavily affect the classification results, a single spelling session for the purpose of eliciting one specific letter is composed of multiple blocks, usually 15 to 20, to eliminate the noisy other effects such as the crowding problems [2]–[5], the human errors and subject's tiredness [6], or repetition blindness problems [7].

Some modifications on the original P300-Speller were made in order to improve the quality of P300 peaks in epochs and to decrease the spelling time for a single session. The original row/column paradigm (RCP) can be tuned into similar counterparts which deal on single letter flashing or region-based flashing paradigm. In RCP, two out of twelve stimuli are the target ones, thus resulting in the target rate of 1/6. Several researches have shown that lowering this rate necessitates the appearance of clearer P300 components in EEG epochs [1]. A novel paradigm called region-based paradigm (RBP) [8] was designed not only to decrease this rate to 1/7 but also to increase the number of letters which can be expressed. The matrix of letters is replaced by the presence of 7 zones on the screen, with each zone contains 7 different letters. Among the original 36 letters of the conventional P300-Speller, 13 more symbols (@, #, %...) were introduced in this paradigm to increase the total number of symbols to 49. The flashing scheme is divided into 2 phases, for zones, or regions, and for letters in one zone. First, 7 regions are intensified as the subject only needs to focus their eyesight on a specific zone. After determining that region, the second flashing phase comes as 7 different letters in that region are flashed in the same way. It should be noted that the other 6 non-target regions are excluded and disappear from the screen for the purpose of

978-1-5090-0890-2/16/$31.00 ©2016 IEEE

RESEARCH ON POSITIVE NARROW BIPOLAR EVENTS IN PADANG

Ariadi Hazmi, Primas Emeraldi, M. Imran Hamid
Dept. of Electrical Engineering
Andalas University
Padang, Indonesia
ariadi@ft.unand.ac.id

Nobuyuki Takagi
Dept. of Electrical and Electronic Engineering
Gifu University
Gifu City, Japan
1-1 Yanagido, Gifu 501-1193, Japan

***Abstract*— In this study, we have examined electric field records from 10 thunderstorm days containing 13 positive narrow bipolar pulses (PNBPs). It was found that PNBP occurrences have a strong relationship with thunderstorm activities. The mechanism of the NBPs was very different from intracloud (IC) and cloud-to-ground (CG) flashes. We also found that the AM values of rise time, full width at maximum time, zero crossing time, overshoot time, pulse duration and overshoot to peak amplitude ratio of the PNBPs were 1.64 µs, 1.32 µs, 9.38 µs, 15.06 µs and 0.31 µs, respectively. The pulse duration range was from 8.45 to 29.06 µs. Comparison with values from previous studies reported by other researchers showed that the mentioned parameters had no strong relationship with latitude or geographic location.**

Keywords—narrow bipolar pulse; cloud flash; ground flash; thunderstorm; lightning

I. INTRODUCTION

Narrow bipolar pulses (NBPs) are identified as one of the intracloud (IC) lightning discharge activities inside thunderclouds. However, the physical mechanism of NBPs remains a mystery. Many researchers have reported that there were two types of NBPs, namely positive narrow bipolar pulses (PNBP) and negative narrow bipolar pulses (NNBP). NBPs have strong radio frequency radiation at several MHz and a short duration with zero crossing (initial positive half cycle) and overshoot (negative half cycle) within several microseconds, followed by or not followed by any other signals [1-4]. NBPs may not be related to ground and cloud flash activities and originate inside the most active thundercloud areas [2]. PNBPs usually occur at lower latitudes than NNBPs. In addition, PNBP occurrences are rare compared to NNBP events [5]. This study is to clarify the relationship between thunderstorm activity and PNBP occurrence. We examined an electric field change data set with 13 PNBPs that were recorded during thunderstorm days in 2015. The characteristics of the PNBPs were statistically analyzed based on electric field change as presented in this paper. All data were also compared to previous researches at different locations and latitudes.

II. OBSERVATION AND DATA

The electric field records containing the PNBPs presented here were recorded from January to December 2015 in Padang, Indonesia (0° N) on 10 thunderstorm days using an electric field mill and a broadband electric field fast antenna. Both electric field sensors on the rooftop of the Electrical Engineering Department Building of Andalas University were located at 13 km from Padang Beach, Indian Ocean at an altitude of 317 m above sea level. The fast antenna with parallel flat-plate configuration was used to detect electric field changes in the thunderclouds. The fast antenna was connected to an amplifier and integrator with a time constant of 100 ms. Furthermore, all signals sensed by this antenna were recorded by a digitizer with a sample rate in the range of 1-4 MS/s and a record length of 250 ns - 1 s. To ensure that the strong electric field of lightning was recorded, the digitizer was set to window trigger mode at a trigger level of 1 V and a pretrigger time of 30% of the record length. The electric field measurement system used was similar to the one used in Hazmi et al. [6-7].

III. RESULTS AND DISCUSSION

In this study, 13 PNBP occurrences were analyzed. A summary of the PNBP events can be seen in Table 1. There are two types of PNBP events; for convenience, type A is called isolated PNBP to indicate that there are no other IC lightning occurrences, while type B is called non isolated PNBP which indicates that the occurrences are preceded or followed by other IC lightning occurrences, as displayed in Figures 1 and 2. The occurrence percentage of type A (46%) was slightly smaller than that of type B (54%). From Table 1, the PNBPs occurred during day and night time with the duration of the thunderstorms varying from 126 to 844 minutes. The background electric field changes of the thunderstorms recorded by an electric field mill sensor for negative and positive polarities varied between 0.284-4.096 kV/m and 0.364-4.094 kV/m, respectively. This indicates that the PNBPs occurred inside the most active thundercloud areas with high electric field. Our observation results were a good agreement with observation of Smith et al. [2]. However, PNBPs also occurred when the thunderstorms detected had a lower electric field, for example thunderstorm numbers 8 and 11 in Table 2. This may be due to the different distance between the PNBPs