Consideration of cost-efficient early warning system utilizing existing analogue radio broadcasting in Indonesia

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Abstract. Early warning systems can increase disaster management capacity. Indonesia worked out the national development policy direction of 2015 – 2019 containing establishment of early warning systems. Japan is operating early warning systems using various ICT systems. Especially an emergency warning broadcasting system to activate corresponding receivers automatically is being operated since 1985. Considering a situation in Indonesia to develop early warning systems from now, an updated early warning broadcasting system can incorporate an earthquake early warning that can provide predicted seismic intensity in each location on the basis of an observed big earthquake prior to actual shaking. The updated system can be cost-efficiently deployed nationwide in Indonesia by combining existing analog radio broadcasting of the public radio network RRI and existing loudspeakers in mosques. Because definitive operation rules need to be established to operate the early warning systems effectively, an operation scenario to provide tsunami warnings is considered as the first step for Indonesia to utilize existing its Warning Receiver System in RRI stations.

1 Introduction

Disaster risk reduction is a vital function for all nations to protect persons, communities, and countries while natural disasters suddenly happen beyond the capability of the power of humanity. The most important thing is preparedness for natural disasters in advance. Early warning systems are important to provide and disseminate disaster information to the public immediately and widely on the basis of reliable information from disaster management agencies. The Sendai Framework for Disaster Risk Reduction 2015-2030 [1], which was adopted at the Third United Nations World Conference on Disaster Risk Reduction in 2015, presents seven global targets to substantially reduce disaster risk and losses by 2030. One of the seven goals is to increase the availability of and people's access to multi-hazard early warning systems and disaster risk information and assessments.

Information and communications technologies (ICT) such as mobile communications (3G, 4G, 5G), SNS (Facebook, Twitter, Instagram, etc.), and broadcasting (digital, mobile) have spread worldwide. Since the progress and penetration of ICT vary depending on country conditions, early warning systems should be constructed by utilizing ICT systems appropriate to the relevant country. In general, broadcasting will be suitable for use in early warning systems due to its wide coverage, lack of congestion, information accuracy, and familiarity to the public.

In this paper, early warning systems using analog radio broadcasting are considered since it covers the whole of almost every country and can effectively inform "not ready" people in emergencies.

2 Emergency warning broadcasting system using analogue radio broadcasting

Japan has many natural disasters including earthquakes, tsunamis, and volcanic eruptions, etc. Therefore, early warning systems using each ICT system are operated on the basis of cooperation between disaster management agencies and telecommunication and broadcasting bodies. Especially, emergency warning broadcasting systems (EWBS) have been developed and operated in both digital and analog broadcasting networks. The EWBS has a unique function that automatically activates the corresponding receivers that are in standby mode by using audio signals. The Asia-Pacific Broadcasting Union (ABU) established an ABU Declaration for implementation of EWBS [2].

2.1 Technical specification

The EWBS consists of the start and end signals shown in Fig. 1 [3, 4]. When an early warning is required, a start signal with appropriate parameters is generated and breaks into ordinary programs to activate the corresponding receivers in the warning areas. When a

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warning is not required, an end signal with appropriate parameters is transmitted to return the receivers to standby mode.

The modulation method is frequency shift keying (FSK) with 640 Hz for space "0" and 1,024 Hz for a mark "1". Therefore, both signals can also be used for the audio alarm to the listeners. The transmission speed is 64 bits per second (bps). The 16-bit Fixed code is used to extract the EWBS signal from the ordinary program. The 16-bit Area classification code is used to distinguish the corresponding receivers in the warning area. The Day/month and Year/time classification codes are used to identify the corresponding warning information. The block constructed of these codes in Fig. 1 is transmitted repeatedly to reliably activate the corresponding receivers.

Fig. 1. The configuration of EWBS signals.

2.1 Operation Example in Japan

The EWBS was developed in Japan, where it has been operated since 1985. This technology has been recognized as one of the IEEE Milestones which are historical technological achievements that have had a significant impact on society and industry more than 25 years after their development [5]. The EWBS is currently operated using not only analog radio broadcasting (AM, FM) but also digital broadcasting (Integrated Services Digital Broadcasting (ISDB)).

The allocation of the codes in the EWBS is shown in Table 1 [6]. In the Fixed code, category 1 is used for large-scale earthquake warning declarations or governor requests based on the relevant act for disaster countermeasures. Category 2 is used for warnings of tsunamis predicted to be 1 m and higher. Categories 1 and 2 share the same end signal. In the Year/time code, 10 years' worth of assignments expressed by 5 bits is assigned cyclically.

Table 1. Allocation of codes in EWBS.

Code Name	Number of Bits	Assignment
Preceding	4	Start: 1100, End: 0011
Fixed	16	Start (Category 1, 2), End
Area	16	53 regions
Day/month	16	31 days and 12 months
Year/time	16	10 years (cycle) and 24 hours

To activate the corresponding receivers, the dedicated Fixed code is received four times or more [7]. This means that the receivers activate automatically when the first Fixed code in the second Block, which follows three Fixed codes in the first Block, is received. This condition ensures the reliable operation of the EWBS by avoiding the wrong activation in the receivers.

3 Early warning system utilizing EWBS in Indonesia

The EWBS in Japan was launched in 1985, and its operation scenario is still based on the meteorological technologies from that time. New early warning systems should be developed while considering their applicability to expected meteorological technologies in the near future. In terms of technical aspects and effectiveness, an earthquake early warning (EEW), which has been provided nationwide in Japan since 2007, is considered as useful information for early warning systems. The EEW is used to announce predicted seismic intensity in each location on the basis of an observed big earthquake prior to actual shaking by utilizing the seismic feature that a fast primary wave of about 7 km/sec. can be detected before the slow secondary wave of about 4 km/sec., which causes shaking is reached [8].

The EEW enables us to take actions to reduce the effects of a predicted shaking of the earthquake such as protecting ourselves from falling objects, turning the gas off, and securing the escape route. Therefore, it is provided for people in Japan through various ICT systems such as mobile communications, web applications and broadcasting. However, the EEW is provided separately from the EWBS since the EEW is difficult to include into the existing operation scenario of the EWBS. The EEW is currently provided by an immediate text or audio with a special chime in broadcasting, not an automatic activation function.

Since Indonesia experiences many earthquakes similarly to Japan, new early warning systems in Indonesia should include the EEW function [9].

3.1 Update of EWBS for fast activation for EEW

The EEW is analyzed on the basis of the velocity difference between the first and second waves of about 7 and 4 km/sec. Since the arrival time difference shorten when the location is close to the seismic center, the EEW will need to be provided as soon as possible. In the

current operation of the EWBS in Japan, the Fixed code needs to be received four times to activate the receivers. In this case, the activation time will be about 1.8 sec. calculated as $(4+96+16)$ bits/64 bps. On the other hand, some methods have been developed provide the EEW through the digital broadcasting systems in Japan, within about one second.

Three methods will be considered to update the EWBS to shorten the activation time:

- 1) Increase the transmission speed from 64 bps
- 2) Decrease the length of the codes from 16 bits
- 3) Decrease the times of the reception of the code from 4 times

Method 1 requires technical evaluations to determine whether it can perform sufficiently. Method 2 will limit available parameters since assigned codes are decreased. Method 3 may decrease the operation reliability by relaxing the condition of the receiver activation. Among the three methods, method 1 will be most desirable if it performs sufficiently for the operation since the configuration can be maintained.

Here, the transmission speed of 128 bps, double to the current speed, is considered as method 1. In this case, the activation time will be about 0.9 sec. calculated as $(4+96+16)$ bits/128 bps without introducing other methods.

3.2 Evaluation system for updated EWBS

The EWBS evaluation system shown in Fig. 2 was developed to verify technical performance for both 64 and 128 bps. The EWBS code generator makes audio signals by using the combination of arbitrary codes, an arbitrary number of repetitions of the Block, the transmission speed of either 64 or 128 bps, and the white noise with a signal-to-noise ratio (SNR) from -6 to 30 dB. The FM receiver with the EWBS function detects the dedicated codes and outputs its log to a PC. The receiving frequency range is from 76 to 108 MHz. The

receiving sensitivity is more than 20 dBμV.

EWBS code generator

FM receiver with EWBS function

Fig. 2. EWBS evaluation system.

3.3 Right Detection Performance Against White Noise

We compared right detection ratios of the dedicated Fixed code (16 bits) between the transmission speeds of 64 and 128 bps when white noise was added. The experimental system is shown in Fig. 3. It consists of a PC with the EWBS code generator, a low-power FM transmitter, and FM receivers with the EWBS function connected to a PC.

Fig. 3. Experimental system for right detection performance.

First, 2,100 dedicated Fixed codes correspond to 700 Blocks, were transmitted through the FM transmitter, and the number of the codes detected in the FM receiver was counted. The right detection ratios were calculated from the number of detected codes in the receiver divided by the number of transmitted codes (2,100). The evaluations were conducted by changing the SNR, and the receiving power. The experimental results are shown in table 2.

Table 2. Right detection performance of dedicated Fixed code (16 bits) against white noise.

Receiving Power	Trans. Speed	Right Detection Ratio Against White Noise (Expressed by SNR)				
		30dB	0dB	-3dB	-6dB	None
55	64	100%	100%	-	100%	100%
	128	100%	100%	100%	98.7%	100%
40	64	100%	100%	-	100%	100%
	128	100%	100%	100%	98.8%	100%
20	64	100%	100%	-	100%	100%
	128	100%	100%	100%	98.5%	100%

These results show that although only a few codes went undetected in the case of the high-noise level (SNR of -6 dB), the right detection performance for 128 bps was almost equal to that for 64 bps whenever the receiving power was changed. This high-noise level condition (SNR of -6 dB) is not required within the coverage area of the existing analog radio broadcasting, so the right detection performance for 128 bps is sufficiently robust to the white noise.

3.4 Wrong detection performance against ordinary radio program

In addition to the right detection performance, we evaluated the wrong detection performance against ordinary programs in analog radio broadcasting because the receiver with the EWBS function may activate automatically by mistake when ordinary programs coincidentally include similar or equal audio components to the dedicated code.

We conducted a long-term observation experiment using actual FM radio broadcasting to evaluate the wrong detection performance for 64 and 128 bps. The experimental system is shown in Fig. 4. The FM receivers with the EWBS function received actual radio programs throughout the day for several months and output their logs to a PC when the dedicated code was observed. To compare the performance for 64 and 128 bps, one receiver detected the dedicated code of 64 bps only and the other detected the code of 128 bps.

Fig. 4. Experimental system for wrong detection performance against ordinary radio program.

We observed FM programs of both NHK (Japan Broadcasting Corporation) in Tokyo for more than three months and RRI (Radio Republik Indonesia) Pro 3 in Jakarta for more than four months. There was no wrong detection of the dedicated code (16 bits) of either 64 or 128 bps. Table 3 shows the experimental results.

Table 3. Wrong detection performance of dedicated Fixed code (16 bits) against ordinary radio programs.

Receiving Area	Receiving Channel	Observation Period	Number of the Wrong Detection
Tokyo	NHK FM	More than 3 months (24, March – 21, Apr.) (24, Apr. – 3, July)	None
Jakarta	RRI Pro 3	More than 4 months (17, May – 18, Sep.)	None

These results show that the wrong detection performance for the transmission speeds of both 64 and

128 bps was sufficiently robust to the ordinary radio programs.

Considering the above discussions and observed performances, the updated EWBS with the transmission speed of 128 bps performs appropriately for an early warning system in Indonesia.

4 Cost-efficient early warning system using existing system in Indonesia

Early warning systems require two characteristics:

- 1) Cost-effectiveness
- 2) User friendliness

Here, a suitable early warning system is discussed with consideration of Indonesia's characteristics.

4.1 Dissemination through RRI's Analogue Radio Network

Broadcasting is generally suitable for use in early warning systems due to its wide coverage, lack of congestion, information accuracy, and familiarity to the public. The Indonesian public radio broadcaster, RRI, already covers about 90% of the population and is widely known to the nation due to its long existence.

The early warning system applying the updated EWBS uses audio signals only, so it can be constructed nationwide by utilizing RRI's existing analog radio networks such as AM and FM. An EWBS code generator should be installed into each RRI station shown in Fig. 5 to generate an original code to activate corresponding receivers in warning areas within the coverage. When a disaster is predicted or has happened, the corresponding RRI station should change its program from the ordinary one to the EWBS and disseminates necessary information related to the disaster provided by disaster management agencies such as Badan Nasional Penanggulangan Bencana (BNPB), Badan Penanggulangan Bencana Daerah (BPBD), Badan Meteorologi, Klimatologi dan Geofisika (BMKG), and so on.

This scenario will be cost effective due to using existing radio broadcasting and user-friendly due to using existing media familiar to the public.

Fig. 5. Required equipment in each RRI station.

4.2 Announcement through loudspeakers in mosques

While ordinary radio programs are broadcast through radio receivers only, the EWBS has a unique function that automatically activates the corresponding receivers in standby mode. Therefore, it can be applied for public

address (PA) systems by inserting the radio broadcasting for the EWBS and relevant information only when a disaster is predicted or has happened.

Indonesia has many mosques equipped with loudspeakers outside to call people to pray. When the loudspeakers in the mosques can be utilized, early warning systems will be constructed nationwide by combining RRI's existing analog radio networks and existing loudspeakers in mosques [10]. A radio broadcasting receiver with the EWBS function should be installed into each mosque as shown in Fig. 6 to activate and relay RRI's announcements to disseminate necessary information only when a disaster is predicted or has happened. In normal times, the receiver with the EWBS function is standby mode. The FM receiver with the EWBS function in Fig. 2 has a switch function that works with the EWBS code detection. Therefore, it can pass daily programs directly to the loudspeakers in normal times and switch to relay radio programs to the loudspeaker when the automatic activation is operated due to the detection of the dedicated code.

This scenario will be cost effective due to using existing loudspeakers and user-friendly due to using existing facilities familiar to the public.

Fig. 6. Required equipment in each mosque.

4.3 Operation rule by disaster management agencies

Definitive operation rules for when the early warning systems can be operated effectively need to be established. For example: in Japan, the EWBS on the basis of warnings of tsunamis predicted to be 1 m and higher and the EEW on the basis of predicted seismic intensity of five and over can disseminate sufficiently since there are definitive rules among relevant agencies. In addition, the definitive rules enable early warning systems to be automatically operated on the basis of the reliable information provided by disaster management agencies without human error.

Although early warning systems need to disseminate information on various disasters [11], tsunami information is considered as the first step in Indonesia. The BMKG provides earthquake and tsunami information officially and has installed Warning Receiver Systems (WRS) in broadcasters including the RRI. An example of information provided via the WRS to radio broadcasters is shown in Fig. 7 [12].

This information includes warning levels such as Major Warning (AWAS), Warning (SIAGA) and Advisory (WASPADA) in each area. Therefore, information necessary to generate the EWBS code to activate the receivers in the dedicated area and to enable

announcers to relay the relevant information and instructions will already be provided for early warning systems for tsunami information when the operation rules are clear among relevant agencies.

Fig. 7. Example of tsunami information via WRS to radio broadcaster.

The assumed operation scenario of the early warning system for a tsunami is as follows:

- 1) Establish definitive operation rules for tsunamis. For example, information shall be provided to people in the area corresponding to Major Warning and Warning.
- 2) Provide tsunami information via the WRS from BMKG to RRI. This is already in operation.
- 3) RRI stations that cover the area corresponding to the Warning generate and transmit the EWBS code to activate the receiver in the mosques in the corresponding area and announce the relevant information on the basis of the WRS.
- 4) The people in the area corresponding to the Warning can be informed via announcements from the loudspeakers in nearby mosques.
- 5) RRI stations that cover the area corresponding to the Warning transmit the EWBS code to return the receiver in the mosques in the corresponding area to the standby mode when the Warning is ended.

A WRS should be installed into each RRI station and preferably connected to the EWBS code generator for automatic operation. Also, the BPBD in the corresponding area should be connected to the local RRI station by secured lines when considering the provision of other disaster information. The required equipment in each RRI station is shown in Fig. 8.

This scenario will be cost effective due to using existing WRS and user-friendly due to expected automatic operation.

Fig. 8. Required equipment in each RRI station between disaster management agencies.

5 Conclusions

An early warning system was considered for Indonesia that utilizes an updated EWBS via analog radio broadcasting. The updated EWBS can automatically activate the corresponding receivers within one second to utilize the EEW. The experimental results show that the updated EWBS also performances robustly enough in terms of both the right detection against the white noise and the wrong detection against the ordinary radio programs.

This early warning system can be cost-efficiently implemented in Indonesia by utilizing existing systems. The combination of the analog radio network of RRI and the loudspeakers in the mosques will the early warning system to be constructed nationwide and be user-friendly due to using existing media/facilities familiar to the public. Definitive operation rules are needed to operate the early warning system effectively, so an assumed operation scenario for tsunami warnings is considered as a first step. The existing WRS installed in the RRI stations by the BMKG provides useful information. Therefore, the WRS should preferably be connected to the EWBS code generator for automatic operation.

This cost-efficient and the user-friendly early warning system will be suitable to increase the disaster management capacity in Indonesia.

References

1. Sendai Framework for Disaster Risk Reduction 2015-2030 (2015)
2. Asia-Pacific Broadcasting Union "ABU Declaration - Implementation of Emergency Warning Broadcasting Systems in the Asia-Pacific Region" (2006)
3. Radiocommunication Sector of International Telecommunication Union, "Use of satellite and terrestrial broadcast infrastructures for a public warning, disaster mitigation, and relief", Rec. ITU-R BT. 1774-2 (2015)
4. Asia-Pacific Broadcasting Union, "Handbook on Emergency Warning Broadcasting Systems" (2009)
5. Japan Broadcasting Corporation, "IEEE Milestones Dedicated for Two Research Results of NHK", Broadcast Technology, No. 65 (2016)
6. Association of Radio Industries and Businesses, "Technical Standard for Emergency Broadcasting Receiver", BTA R-001 (in Japanese) (1986)
7. Japan Electronics and Information Technology Industries Association, "Methods of Measurement for Receivers for Emergency Warning Broadcast System", EIAJ CPR-2202 (in Japanese) (1992)
8. Japan Meteorological Agency, "Earthquake Early Warning System", <http://www.jma.go.jp/jma/en/Activities/eeew.html>
9. M. Kamei, "A Study on Application of Emergency Warning Broadcasting System by Analogue Radio for Overseas Expansion", BCT2017-59 (in Japanese) (2017)
10. F. Ndolu, "The Roles of Broadcasters in Disaster Reportage: A Lessons Learned from Tsunami Reportage in Indonesia", 21st JAMCO Online International Symposium (2013)
11. National Disaster Management Agency, "Disaster Management Policies and Strategies 2015-2019" (2016)
12. INFORMATION GUIDEBOOK Tsunami Early Warning for Broadcasting Institutions in Indonesia (2012)