Detecting Broadcaster Transmitted Earthquake Early Warning Signal with AC Parity for ISDB-T Digital Television Receivers

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***Abstract*—When significant disaster occurs, certain television broadcasters can wake up their receivers with a special signal. Such wake-up televisions are already available in the world. In ISDB-T (Integrated Services Digital Broadcasting-Terrestrial) digital television in Japan, there are two wake up methods: Emergency Warning System (EWS) and Earthquake Early Warning (EEW). A wake-up indication of EWS comes from a single bit of the control channel and a method of efficiently detecting the wake up signal with parity variations is known. The EEW wake-up signal, however, contains detailed information messages in addition to the wake-up indication. This paper focuses on determining only the EWS wake-up indication and proposes a method of detecting the indication.**

***Index Terms*—terrestrial digital television broadcasting; ISDB-T; earthquake early warning; EEW; seismic motion warning; emergency warning system**

I. Introduction

Prompt alert of disaster would significantly reduce the damages and the wake-up television receivers are available now. EAS (Emergency Alert System) on ATV (Advanced Television) is in operation in United States and other countries. EWS (Emergency Warning System) on DVB-T (Digital Video Broadcasting-Terrestrial) is used in European and other countries [1]. Both EWS on ISDB-T (Integrated Services Digital Broadcasting-Terrestrial) in Japan and other countries and EAS on mobile digital television of T-DMB (Terrestrial Digital Multimedia Broadcasting) in South Korea use the control channel to broadcast an emergency signal [1], [2]. The wake-up signal is sent in the digital format in ISDB-T EWS and T-DMB EAS.

The nature of such wake-up television is in both the broadcaster and receiver sides. A broadcaster would send a wake-up signal with the normal television signal by a request of the local government or the meteorological agency. At a receiver side, some parts such as the power supply, the tuner, and the controller are active even it is in idle. The receiver would wake up itself when it receives a wake-up signal.

As an alternative method of waking up, EEW (Early Earthquake Warning) is available in ISDB-T in Japan. The EWS warns earthquake and tsunami forecasts with a latency of several seconds. A single bit in the control signal shows the wake-up indication of EWS. After reception of the EWS wake-up indication, a receiver would further receive the detailed message sent in the transport stream. It enables the receivers to detect EWS wake-up signal by receiving the control channel only. It is intended for reducing power consumption of idle receivers. The EEW alerts urgent earthquake crisis and the latency is within a second. The wake-up indication and the detailed message are sent in the same control channel. Not only a wake-up indication, but also information on earthquake such as the focus and magnitude is rapidly transmitted through the EEW.

A method of detecting EWS wake-up signal is proposed assuming broadcasters do not change the control message except for the EWS wake-up indication [3]. The control signal employs the $(184, 102)$ shorten error correction code of the $(273, 191)$ difference-set cyclic code. This method utilized that a single bit change of the EWS wake-up indication varied 35 bits out of the 82-bit parity. The majority decision of the 36 bits reliability determins whether the EWS wake-up is issued or not. The parity bits are introduced for the error correction, but the author pointed out that a lower false alarm probability could be achieved with the majority decision rather than the error correction.

The EEW contains the detailed message, and several bits change when the EEW wake-up indication is issued. Therefore, it is virtually impossible to focus which parity bits are inverted by an issue of the EEW wake up. In this paper, we focus on a mobile television receiver of only detecting whether the EEW wake up is issued or not. A mobile receiver would encounter Rayleigh fading and it results in higher false alarms and misdetections. This paper proposes a majority decision method of detecting EEW wake-up indication.

II. Interpreting EEW Messages

A. Two Control Channels of ISDB-T

There are two control channels in ISDB-T. One is TMCC (Transmission and Modulation Configure Control), and it usually tells modulations and error correction redundancies of audio, video, and data transmissions for fixed and mobile receivers. The wake-up indication of the EWS is on TMCC. Another is AC (Auxiliary Channel), and it usually transfers the control and timing signals from the broadcasting master station

[1] http://www.dvb.org/resources/public/factsheets/DVB-EWS-Fact-sheet.pdf

to the broadcasting repeater stations. When the broadcaster sends the early warning of earthquake, the EEW signal is sent on AC. As of this point, ISDB-T only in Japan sends an EEW signal.

Both the TMCC and AC message contains 204-bit length information including the parity (the first 19 bits are not protected by the error correction) and employs DBPSK (differential bi-phase shift keying) modulation. The bit rate is 992 bit/s and the information is sent cyclically in every 0.2 second.

B. AC Format

AC contains a 16-bit-length synchronization word. In normal, AC is used for a broadcaster. Television receivers cannot interpret the AC messages, because the synchronization word and the signal format are not disclosed to public.

When a broadcaster advises an EEW message, AC contains following bit sequence [1]:

- synchronizing signal (16-bit-length)
- start or ending flag (the wake-up indication, 2-bit-length)
- update flag (2-bit-length)
- signal identification (3-bit-length)
- detailed seismic motion warning information (88-bit-length)
- CRC (10-bit-length)
- parity (82-bit-length)

An idle receiver would wake up when it receives the wake-up indication of 11. The update flag indicates change in the information; the signal identification indicates classification of test, with or without detailed seismic motion warning information. The CRC is used for detecting errors of information between the signal identification and the detailed seismic motion warning information. The parity is for correcting transmission errors between the start or ending flag and the CRC. Broadcaster identification is set to a part of the detailed information when there is no detailed information available at the broadcaster.

C. Error Correction of AC for Conventional Receivers

ISDB-T uses the $(187, 105)$ shorten code of the $(273, 191)$ difference-set cyclic error correction codes for AC [4]. The code is based on BCH codes and is originally proposed by Weldon. The code can be decoded with the majority decision. The generating polynomial is $x^{82}+x^{77}+x^{76}+x^{71}+x^{67}+x^{66}+x^{56}+x^{52}+x^{48}+x^{40}+x^{36}+x^{34}+x^{24}+x^{22}+x^{18}+x^{10}+x^{4}+1$. Because the Hamming weight is 18 (it is equal to the number of the generating polynomial terms), the code can correct error less or equal to 8 bits. The method of correcting errors and the performance analysis under fading can be found in [5] (it is for TMCC, but the same analysis can be applied for the error correction).

D. Bit Error Rate of DBPSK Modulated Signal in Fading Environments

A bit error rate, P_e, of DBPSK in AWGN (additive white Gaussian noise) is known and it is [6]

$$P_e = \frac{1}{2}\exp(-\gamma) \tag{1}$$

where γ is energy per 1 bit relative to the noise power density and it is often referred to as E_b/N_0. A mobile receiver would encounter Rayleigh fading and P_e is

$$P_e = \frac{1}{2}\left[\frac{1+\gamma(1-\rho_C)}{1+\gamma}\right], \tag{2}$$

where ρ_C is $J_0(2\pi f_D T_s)$, f_D is the maximum Doppler frequency, $J_0(\cdot)$ is the first kind Bessel function of zero order. For $\gamma \to \infty$,

$$P_e = \frac{1}{2}(1-\rho_C). \tag{3}$$

III. Proposed Detection of Wake-Up Indication with Majority Decision

As described in Sect. II-B, there is various information such as the detailed seismic motion warning information in AC when an EEW message is advised.

At the end situation, however, most of all the EEW information bits are disused. Then, the broadcaster no longer does not send information any more. Therefore, all EEW messages except for the end situation are assumed to be EEW wake-up indication here. The proposed method can be described with following steps:

1) the receiver is waiting for an EEW synchronization word on AC,
2) the receiver counts the number of active bits among the start or ending flag and the specific parity bits,
3) if the number is less than a threshold, it is not the end situation and the receiver wakes up.

To do this, the parity bit sequence with the broadcaster identification should be calculated so that receivers can know the end situation.

When the end situation is advised, the start or ending bits (B_{17}, B_{18}) are 00, the signal identification bits (B_{21}, B_{22}, B_{23}) are also 000. Then, the parity bits of x^{80}, x^{77}, x^{72}, x^{67}, x^{65}, x^{60}, x^{57}, x^{55}, x^{52}, x^{51}, x^{48}, x^{46}, x^{41}, x^{40}, x^{35}, x^{34}, x^{32}, x^{30}, x^{26}, x^{25}, x^{22}, x^{20}, x^{19}, x^{16}, x^{15}, x^{12}, x^{11}, x^{10}, x^{8}, x^{5}, x^{3} indicate the specific value defined by the broadcaster identification. Therefore, there are 36 bits available for the majority decision.

The performance is evaluated in terms of misdetection probability ($P_{\rm md}$) and false alarm probability ($P_{\rm fa}$). $P_{\rm md}$ is the complementary probability the 18 synchronization bits are received correctly and the number of the agree bits of the 36 bits is less than 18,

$$P_{\rm md}^{\rm prop} = 1-(1-P_e)^{16}\cdot\left\{\sum_{k=0}^{18} {}_{36}C_k\,(1-P_e)^{36-k}\cdot P_e^k\right\}. \tag{4}$$

On the other hand, $P_{\rm fa}$ is the probability the synchronization bits are received correctly and the more than the 19 bits out of the 36 bits disagree,

$$P_{\rm fa}^{\rm prop} = (1-P_e)^{16}\cdot\left\{\sum_{k=19}^{36} {}_{36}C_k\,(1-P_e)^{36-k}P_e^k\right\}. \tag{5}$$

These probabilities for the conventional method of using error correction for the parity can be obtained as the same way.

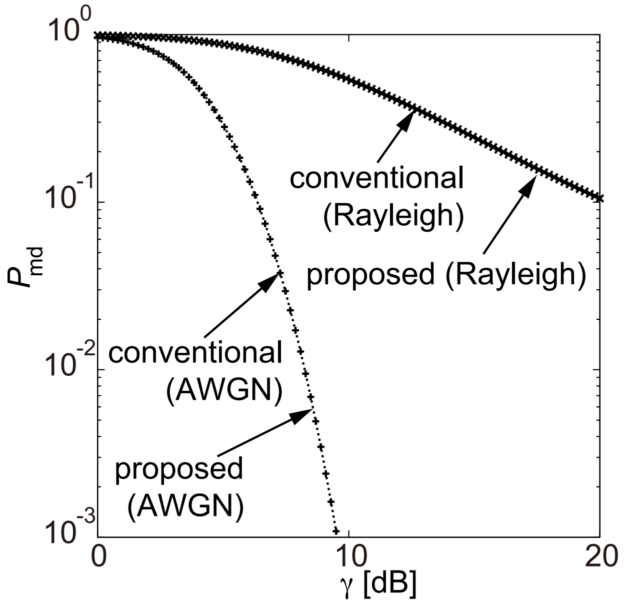

Fig. 1. Comparison of misdetection probabilities (P_{md}) in AWGN and Rayleigh fading environments.

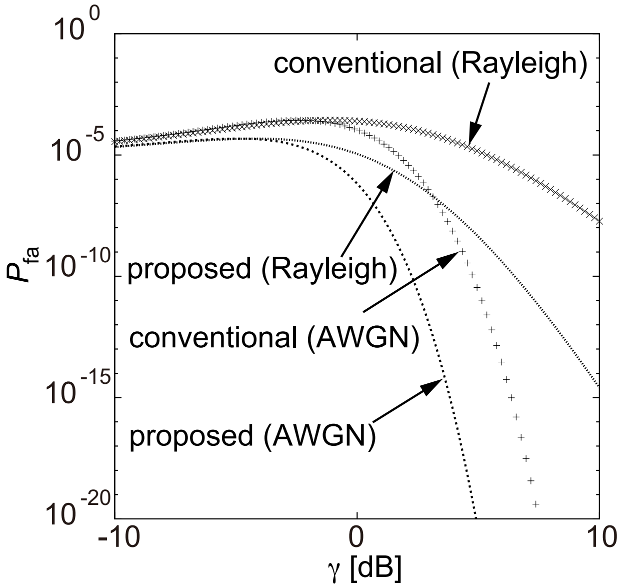

Fig. 2. Comparison of false alarm probabilities (P_{fa}) in AWGN and Rayleigh fading environments.

P_{md} is the complementary probability the synchronization bits and the start or ending bits are correctly received (each of the latter probability is the number of error is less than 8 bits for the 17 bits with the error probability of P_e, see [5]),

$$P_{\mathrm{md}}^{\mathrm{conv}} = 1 - (1 - P_e)^{16} \cdot \left\{ \sum_{k=0}^{8} {}_{17}C_k \, (1 - P_e)^{17-k} \cdot P_e^k \right\}^2 . \tag{6}$$

P_{fa} is the probability the synchronization bits are received correctly and that one of the start or ending bits are wrongly received,

$$P_{\mathrm{fa}}^{\mathrm{conv}} = (1 - P_e)^{16} \cdot \left[1 - \left\{ \sum_{k=0}^{8} {}_{17}C_k \, (1 - P_e)^{17-k} P_e^k \right\}^2 \right] . \tag{7}$$

IV. Performance Evaluation

A center frequency of 600 MHz was assumed in the evaluation. Performance of the conventional and proposed methods is compared in both AWGN and Rayleigh fading environments.

First, P_{md} of both the conventional and proposed method in AWGN are calculated substituting Eq. (1) with Eqs. (4) and (6). P_{md} in Rayleigh fading environments are also obtained using Eqs.(2), (6), and (4) by assuming the velocity of 10 m/s. They are plotted in Fig. 1 as a function of E_b/N_0 (γ). P_{md} decreased as an increase in γ. This figure also showed that P_{md} for the proposed method was almost same as P_{md} for the conventional method. P_{md} in Rayleigh fading environment was always higher than P_{md} in AWGN for an entire range of γ, because P_e in Rayleigh fading environments always was higher than P_e in AWGN. The proposed method did not increase P_{md}.

Next, P_{fa} for the conventional and proposed methods are also compared using Eqs.(1), (2), (5), and (7). P_{fa} as a function of γ is plotted in Fig. 2. P_{fa} showed convex shape as an increase in γ. P_{fa} in Rayleigh fading environment was higher than P_{fa} in AWGN as same as the case of P_{md}. According to the Fig. 2, P_{fa} for the proposed method is lower than P_{fa} for the conventional method at almost all regions of γ. For example in the Rayleigh fading environments at γ of 10 dB, P_{fa} for the conventional and proposed methods were 1.37×10^{-8} and 1.35×10^{-15}. Because AC is sent about 5 frames in a second, the false alarm corresponds the conventional method wrongly alerts an EEW wake-up indication about every 168 days, but the proposed method do more than 4.68×10^6 years.

For comparing the conventional and proposed methods, P_{fa} as a function of P_{md} is calculated and shown in Fig. 3. P_{fa} for the proposed method was lower than that for the conventional method at the same P_{md}. Especially for a lower P_{md} region (a higher γ), the proposed method significantly reduced P_{fa}.

For sufficient large γ, P_{fa} in Rayleigh fading environments for various velocities, v are compared and are shown in Fig. 4. A center frequency of 600 MHz was also assumed in the calculation. In general, P_{fa} increased as an increase in v. An increase in v diminished reduction of P_{fa} due to the proposed method.

V. Conclusion

In this paper, the method of receiving ISDB-T EEW signals for mobile television receivers was proposed. The proposed method focused on detecting the wake-up indication. Because there are few information sent when the end situation of an EEW message is advised, a receiver of the proposed method tries to detect the end situation of the EEW message and alerts when the message is not end one. The detection

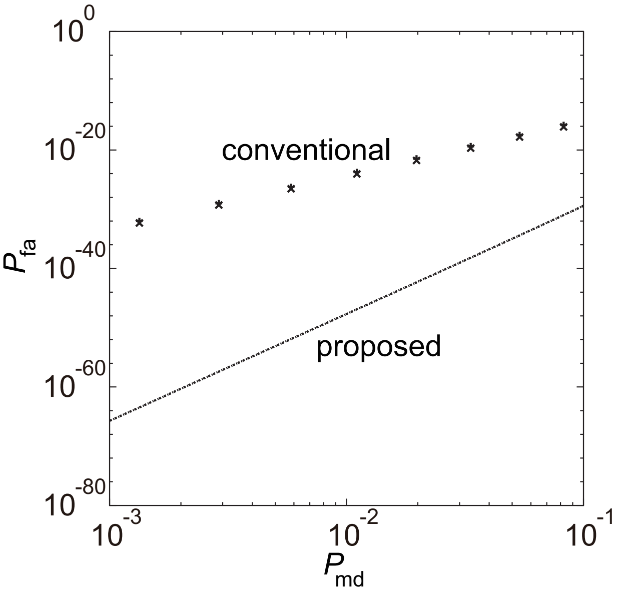

Fig. 3. False alarm probability ($P_{\rm fa}$) as a function of misdetection probability ($P_{\rm md}$).

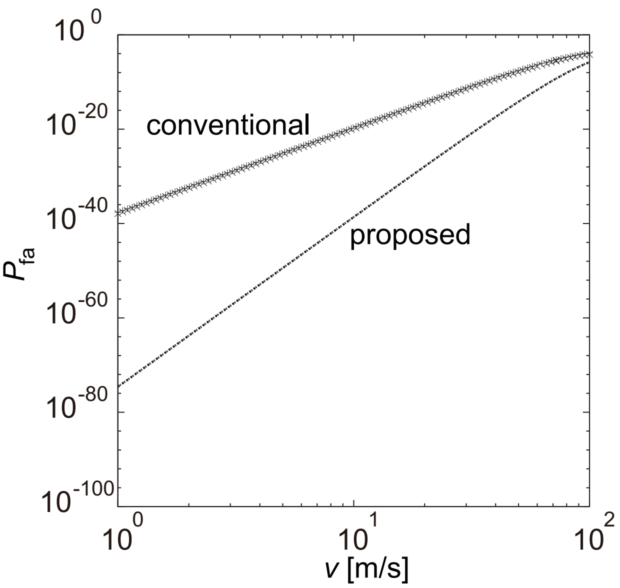

Fig. 4. Comparison of false alarm probabilities ($P_{\rm fa}$) as a function of velocity, v.

could be accomplished by majority decision of specific bits including parity bits. The result showed the proposed method significantly reduced the false alarm probability while did not increase the misdetection probability.

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