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Majority Determination and Subcarrier Diversity of Detecting Broadcaster Advised Emergency Wake-Up Signal for ISDB-T Television Receivers

Satoshi Takahashi

Graduate School of Information Sciences, Hiroshima City University
3–4–1 Ozuka-Higashi, Asa-Minami, Hiroshima 731-3194, Japan
Email: s.takahashi@m.ieice.org

Abstract—In an emergency, a broadcaster would send a special signal to wake up their idle receivers. In ISDB-T (Integrated Services Digital Broadcasting-Terrestrial) digital television standard, the emergency wake-up signal is sent on one of the control signals. Since the control signal is sent over several subcarriers that contain the same information, the subcarrier diversity is possible for reliably determining the signal. ISDB-T broadcasting signal carries video contents not only for fixed receptions but also for mobile receptions. Therefore, this paper focus on determining the wake-up signal for mobile receivers, and the performance with use the subcarrier frequency diversity is evaluated in terms of the misdetections and false alarms.

1. Introduction

Emergency wake-up of idle television receivers has been available in many countries. Such a receiver continues to receive a broadcaster signal when it is idle. In emergency, the broadcaster would send a special signal to wake up their receivers. The world television standards of ATSC (Advanced Television Standard Committee), DVB-T (Digital Video Broadcasting - Terrestrial), and ISDB-T (Integrated Services Digital Broadcasting - Terrestrial) have their own emergency wake-up procedures [1]. Except for others, ISDB-T sends the emergency wake-up signal on their control signal. The purpose of using the control signal is to decrease the power consumption of the idle receivers [2].

In this paper, we focus on a method of receiving the ISDB-T emergency wake-up signal for idle receivers. An ISDB-T broadcaster simultaneously sends programs both for fixed receptions and for mobile receptions within a single broadcasting bandwidth. Therefore, we focus on mobile idle receivers that face rather higher bit errors than fixed receivers face. The error concealment of CODEC (coder and decoder) in these equipments alleviates degradation due to the bit errors in the audio and visual. However, we cannot rely on the error concealment for detecting the emergency wake-up signal since the existence of the wake-up signal is rare in general.

An ISDB-T broadcasting signal is sent by BST-OFDM (Band Segmented Transmission - Orthogonal Frequency Division Multiplexing) with 5,616 data subcarriers and one phase reference subcarrier. The wake-up signal is sent on TMCC (Transmission and Multiplexing Configuration Control) signal, one of the two control signals. TMCC information transfers not only the emergency wake-up signal but also the reception control to the receivers. The information includes the modulations, the coding rates, and the interleave length for fix and mobile receptions. There are 52 TMCC signal subcarriers assigned within the television bandwidth (four TMCC subcarriers within the mobile reception bandwidth), and they have the same TMCC information. The TMCC information consists of 204 bits. DBPSK (Differential Bi-Phase Shift Keying) modulation at a rate of 992 bit/s is employed for the TMCC signals. The wake-up signal is assigned at 26th bit on the TMCC information. There are 82 parity bits for the TMCC information of 102 bits.

A dedicated emergency wake-up receiver was proposed [1]. The receiver determines single bit of the wake-up signal. The receiver activates by decoding the unique word at the beginning of the TMCC information and inactivates after reception of the wake-up signal of the 26th bit. The author of reference [3] proposed the majority determination of both the wake-up signal and parity bits assuming the TMCC information except for the wake-up signal does not change before and after the emergency wake-up signal is issued.

For reducing both the wrong detection and increasing the sensitivity of the wake-up signal, this paper proposes combining the parity method and the subcarrier diversity within the bandwidth for mobile receptions.

2. Wake-up Signal Determination for Idle Receivers

2.1. Bit Error Rate of Wake-Up Signal in Mobile Reception

The bit error rate P_e of DBPSK modulated signal in AWGN (additive white Gaussian noise) is well known,

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

where γ is E_b/N_0.

In mobile environments, a signal arrived at the reception antenna consists of reflected and refracted radiowaves due

[1] http://www.dibeg.org/news/2008/0802Philippines_ISDB-T_seminar/Presentation5.pdf

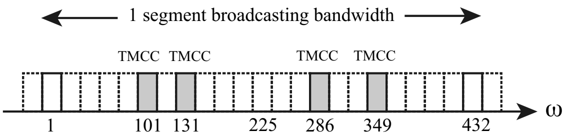

Figure 1: The TMCC subcarriers frequency assignment in a mobile reception bandwidth.

to the surrounding objects. The amplitude and phase of the signal vary as the antenna moves and it is referred to as Rayleigh fading. P_e under the Rayleigh fading is [4]

$$P_e = \frac{1}{2} \cdot \frac{1+\gamma(1-\rho_C)}{1+\gamma}, \tag{2}$$

where ρ_C is the correlation in duration between the current and preceding bit signals, and is expressed under "uniformly spread scatterer" as

$$\rho_C = J_0(2\pi f_D T_s), \tag{3}$$

where $J_0(\cdot)$ is the zero-th order Bessel function of the first kind, $f_D = v/\lambda$ [Hz] is the maximum Dopper frequency, v is the velocity of the receiver [m/s], λ is the wavelength, T_s [s] is the symbol duration.

2.2. Bit Error Rate Reduction with Subcarrier Diversity

The TMCC signal subcarriers are assigned in unequally frequency separations (Fig. 1), and the frequency separation is much wider than the multipath correlation bandwidth (the bandwidth where the two signal within the bandwidth are correlated). Therefore, the maximal combining diversity with the uncorrelated subcarriers would increase the signal strength and reduce P_e. P_e with four subcarrier diversity in a Rayleigh fading environment is also obtained as [4, chap.6.3.3]

$$P_e = \frac{1}{2}\left\{\frac{1+\gamma(1-\rho_C)}{1+\gamma}\right\}^4. \tag{4}$$

Figure 2 compares the bit error rates. A frequency of 600 MHz, a receiver velocity of 1 m/s were assumed to calculate the bit error rates with single subcarrier reception and four subcarrier diversity were assumed in this figure. From the figure, the subcarrier diversity significantly decreased P_e.

2.3. Determination of Wake-Up Signal

The author of [3] pointed out that most of the ISDB-T broadcasters in Japan used the same TMCC information and a change in the wake-up signal leaded to 35 bits changes out of the 82 parity bits. The author proposed the majority determination of the wake-up signal among the 36 bits (Fig. 3) by assuming the broadcaster did not change the TMCC information except for the wake-up signal.

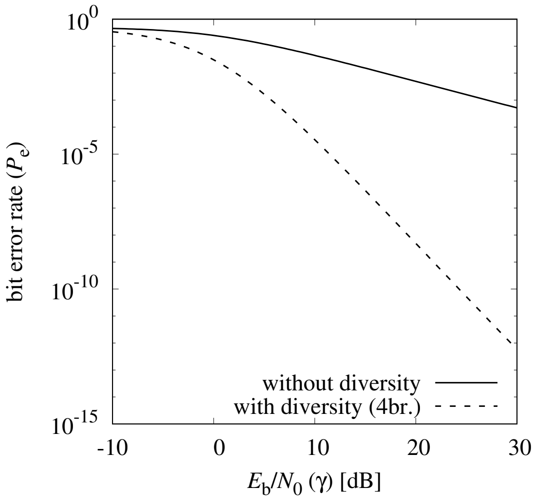

Figure 2: P_e comparison between single subcarrier reception and four subcarrier reception.

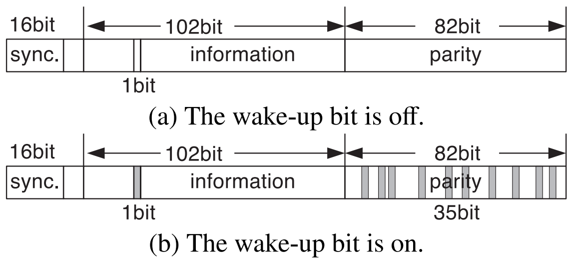

Figure 3: The variation in parity bits as a change in the wake-up signal.

The parity is for the error correction, and the performance of the error correction has been evaluated by computer simulation with random bits [5]. The author of [6] analytically obtained the performance using the expectation calculation of the majority determination that can decode the difference-set cyclic codes. The parity of TMCC information

3. Performance of Determining Wake-Up Signal

The misdetection probability P_{md} and false alarm probability P_{fa} of the single bit detection (here, we denote it as "single" from now on), the error correction ("ec"), and the parity method ("parity") are evaluated. The misdetection means that a receiver wrongly misses wake-up signals, and the false alarm shows the receiver wrongly advises emergency. P_{md} and P_{fa} for "single" and "parity" can be obtained using [3] and those for "ec" is in [6].

P_{md} in Rayleigh fading environments is obtained using Eq.(2) and is plotted in Fig. 4. In the figure, a frequency of 600 MHz and a receiver velocity v of 1 m/s were also assumed. There are 6 P_{md} plots in the figure; they are for

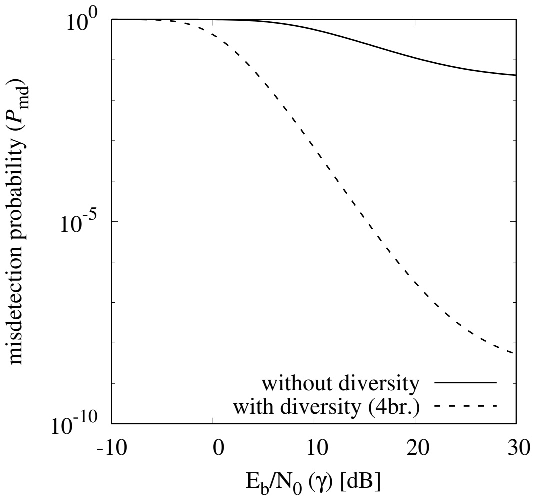

Figure 4: Comparison of P_{md} as a function of γ.

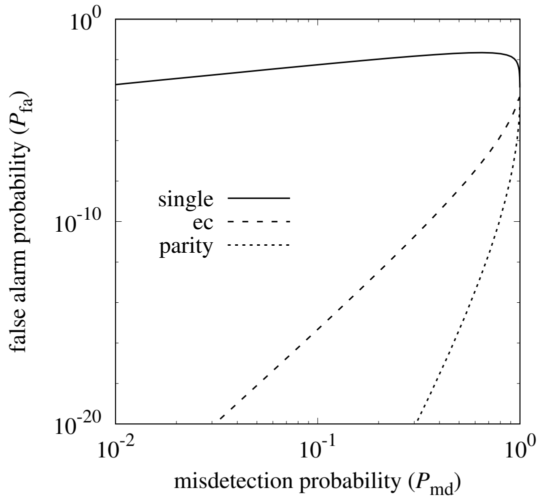

Figure 6: P_{fa} as a function of P_{md} for various γ.

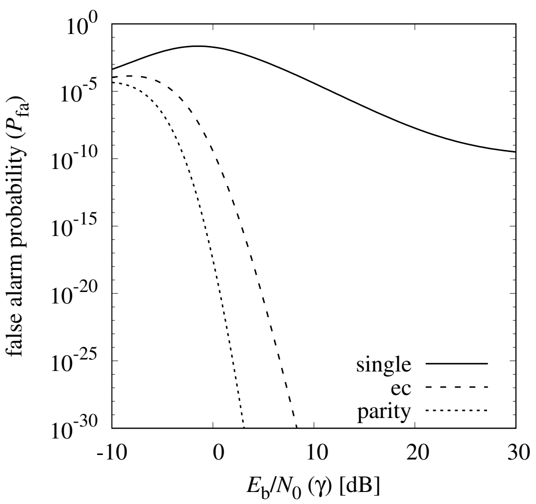

Figure 5: Comparison of P_{fa} as a function of γ.

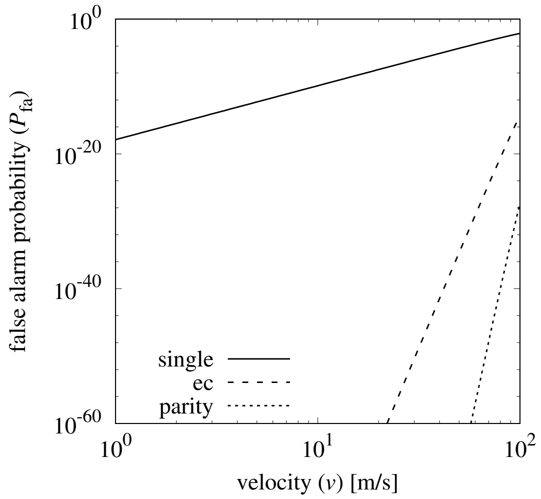

Figure 7: P_{fa} as a function of v for $\gamma \to \infty$.

"single," "ec," and "parity" with and without the subcarrier diversity. Though P_{md} for the the three methods were almost the same, P_{md} with the subcarrier diversity differed. P_{md} with the four subcarrier diversity at γ of 30 dB was 10^{-9} order. In contrast, those without the subcarrier diversity was 10^{-2} order. For decreasing P_{md}, it is necessary for diversity reception.

Therefore, we only evaluate P_{fa} with the subcarrier diversity and the result is compared in Fig. 5. P_{fa} as a function of γ were convex shaped. An increase in γ decreased P_e, and it leaded to decrease in P_{fa}. On the other hand, P_{fa} decreased in a higher γ region, since the receiver occasionally missed the beginning of the TMCC information and it resulted in occasional miss the wake-up signals. As an increase in γ, P_{fa} of "ec" and "parity" decreased rapidly. P_{fa} of "single" showed an error floor. Comparing it with "single,", "parity" decreased P_{fa} one ten-thousands.

In general, loosening the determination condition decreases P_{md}. However, it results in a higher P_{fa}. For comparing the three methods, P_{fa} as a function of a P_{md} is plotted in Fig. 6. At a given P_{md}, P_{fa} of "parity" showed the lowest value than others, and "parity" significantly decreased P_{fa} with the subcarrier diversity.

Because P_e increases as an increase in the velocity v, P_{fa} for the three methods as a function of v at the large limit of γ are compared and depicted in Fig. 7. P_{fa} monotonically increased as an increase in v. However, "parity" decreased P_{fa} significantly.

4. Conclusion

In this paper, the misdetections and false alarms of the emergency wake-up signal on ISDB-T terrestrial digital television broadcasting were evaluated. The wake-up signal is sent on a control signal, and there are four subcarriers that are placed unequal separation in frequency. Therefore, it is possible to employ the subcarrier diversity for reliably determining the wake-up signal. In this paper, the performance was evaluated in terms of the misdetection and false alarm probabilities. The misdetection probabilities were almost the same among these three methods, and the subcarrier diversity significantly reduced the misdetection probability. On the other hand, the parity method reduced the false alarms than others did. The subcarrier diversity and the parity method mutually reduced the false alarms.

Acknowledgments

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