Detection of Emergency Wake-Up Trigger Signal with TMCC Parity and Subcarrier Frequency Diversity for ISDB-T Digital Television Receivers

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***Abstract*—When emergency alert is advised, some digital television broadcasters would send a special control signal to wake up receivers. In ISDB-T (Integrated Services Digital Broadcasting-Terrestrial) digital television standard, the special control signal is referred to as TMCC (Transmission and Modulation Configuration Control). It is capable of handling such emergency wake up and is also used for identifying the transmission parameters such as the modulations and coding rates. Because the transmission parameters are usually fixed, the use of the parity in the special control signal has been proposed for detecting emergency wake-up trigger. Though the parity method reduces the false alarm probability, it offers the same misdetection probability as the conventional wake-up trigger detection. Therefore, in this paper, the frequency diversity as well as the parity is used for further reducing the misdetection probability. The result showed the proposed combination of the parity detection and the frequency diversity complementary reduced probabilities both of the false alarm and the misdetection.**

I. INTRODUCTION

When felt tremble on the ground, we would turn on a television to listen information on the earthquake. Prompt alert for emergency is important and it is natural to come up with an automatic wake-up television receiver. The idea has been realized by broadcasting special signal from the broadcaster. In the idle television receiver, some parts such as the tuner and power supply controller are still active, and the receiver continues to receive a broadcaster signal until it determines emergency alerts.

Video contents in digital televisions are multiplexed in transport stream (TS). ISDB-T uses OFDM (Orthogonal Frequency Division Multiplexing) and the transmission bandwidth of 5.6 MHz. The bandwidth is logically divided into 13 subbands (called segments) and they are grouped by 3 layers, A-layer, B-layer, and C-layer. Each layer would employ mutually different modulation and coding rate from others. Therefore, the control signal, called TMCC, is necessary for indicating the modulations and the coding rates, and the wake-up trigger is also in TMCC [1]. In ISDB-T, the emergency wake-up procedure is defined as EWS (Emergency Warning System).

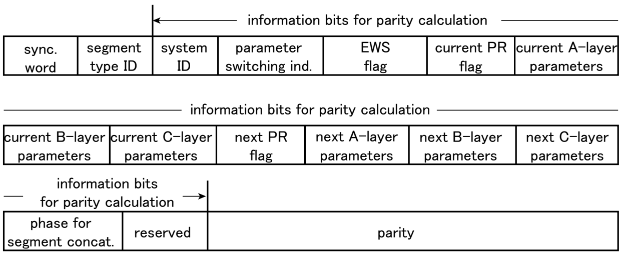

Fig. 1. The TMCC message.

On the other hand for mobile reception, it is important to decrease power consumption. Periodical sleep of the equipment during a certain time was proposed [2]. Decreasing the false alarm probability of wake-up trigger also leads to reduce the power consumption. Reference [3] proposed a method of reducing the false alarm probability. There are parity bits in TMCC for correcting errors through the transmission, and the author used the parity changes for detecting the wake-up trigger. The author assumed the ISDB-T broadcasters did not change TMCC message except for the wake-up trigger when advised an emergency. In this paper, for decreasing probabilities both of the false alarm and the misdetection, the use of the frequency diversity in addition to the TMCC parity is proposed.

II. RECEPTION OF EMERGENCY WARNING SIGNALS

A. *Performance of TMCC Reception in Mobile Environments*

TMCC is periodically sent in a 0.2-s cycle at 992 bit/s by DBPSK modulation and it consists of 204-bit message as shown in Fig. 1. Because the ISDB-T signal contains 4 TMCC subcarriers in a segment [1], a four branch frequency diversity within a segment is feasible. In Fig. 1, the emergency wake-up trigger bit is described as the EWS flag.

The bit error rate (BER), P_e, as a function of E_b/N_0, γ, for AWGN is

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

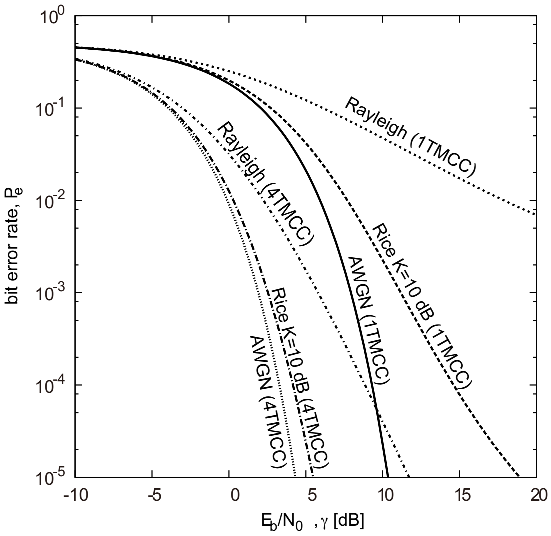

Fig. 2. P_e for DBPSK in AWGN, Rice, and Rayleigh fading environments.

Applying the moment generating function (MGF) method [4, chap.6.3.3], we obtain P_e for Ricean fading (the factor of K) and Rayleigh fading are derived using Eq. (1) as

$$P_e = \frac{1+K+\gamma(1-\rho_C)}{2(1+K+\gamma)} \exp\left(-\frac{K\gamma}{1+K+\gamma}\right), \text{and} \quad (2)$$

$$P_e = \frac{1+\gamma(1-\rho_C)}{2(1+\gamma)}, \quad (3)$$

where ρ_C is the spatial correlation function and it is $J_0(2\pi f_D T_s)$ for uniformly spread scatterers surrounding the receiver, $J_0(\cdot)$ is the first-kind Bessel function, f_D is the maximum Doppler frequency, and T_s is the symbol duration.

B. Frequency Diversity Reception of TMCC

Here we consider frequency diversity reception of TMCC. Applying the MGF method again [4, chap.7.4.1], we also obtain the average P_e for the maximal ratio combining diversity with M uncorrelated diversity branches. P_e for AWGN, Ricean, and Rayleigh fading are

$$P_e = \frac{1}{2}\left\{\exp\left(-\frac{K\gamma}{1+K+\gamma}\right)\right\}^4, \quad (4)$$

$$P_e = \frac{1}{2}\left\{\frac{1+K+\gamma(1-\rho_C)}{1+K+\gamma}\exp\left(-\frac{K\gamma}{1+K+\gamma}\right)\right\}^4, \text{and} \quad (5)$$

$$P_e = \frac{1}{2}\left\{\frac{1+\gamma(1-\rho_C)}{1+\gamma}\right\}^4. \quad (6)$$

They are compared in Fig. 2. In this comparison, a frequency of 600 MHz, v of 10 m/s were assumed. An increase in γ decreased P_e, P_e for Rayleigh fading was higher than P_e for Ricean fading, and P_e for Ricean fading was higher than P_e for AWGN. The result indicated diversity reception reduced P_e, especially for Rayleigh fading.

III. PROPOSED TMCC PARITY METHOD AND SUBCARRIER FREQUENCY DIVERSITY

A. Key Idea of TMCC Parity Method

Here, we assume the broadcasters do not change TMCC message except for the EWS flag when an emergency alert is advised. Then, the proposed TMCC parity method uses the TMCC parity for determining the EWS wake-up trigger, not for error correction of the TMCC data [3]. Under the assumptions, a change in the EWS flag leads to TMCC parity variation, and the TMCC parity method detects the wake-up trigger by the majority decision of agreeing the corresponding bits as the 26th-bit (EWS flag) is 1, the 122nd-bit is 1, the 124th-bit is 0, and so on. Because the bit number of parity variations is 36, the receiver determines the wake-up trigger activation by agreeing more than the 18 matching bits.

B. False Alarm and Misdetection Probabilities

The proposal is evaluated in terms of the misdetection probability, $P_{\rm md}$, and the false alarm probability, $P_{\rm fa}$. The misdetection means the receiver missed the wake-up trigger, and the false alarm means the receiver wrongly alerts when the wake-up trigger is not present. We define the conventional method determines emergency wake-up only by the EWS flag.

$P_{\rm md}$ for the conventional method is the complement probability that 16 bits of the synchronization word agrees and that 1 bit of the EWS flag is detected during an emergency trigger is sent, and it is

$$P_{\rm md}^{\rm conv} = 1 - (1-P_e)^{17}. \quad (7)$$

As Eq.(7), $P_{\rm md}$ is a monotone increasing function of P_e. $P_{\rm md}$ for the TMCC parity method is also the complement probability the synchronization word agrees and that more than 18 bits of the 36 corresponding bits agree, and it is

$$P_{\rm md}^{\rm prop} = 1-(1-P_e)^{16}\cdot\left\{\sum_{k=0}^{18} {}_{36}C_k\,(1-P_e)^{36-k}\cdot P_e^k\right\}. \quad (8)$$

On the other hand, $P_{\rm fa}$ for the conventional method is derived the synchronization word matches while the EWS flag is wrongly determined, and it is

$$P_{\rm fa}^{\rm conv} = (1-P_e)^{16}\,P_e. \quad (9)$$

$P_{\rm fa}$ for the TMCC parity method is obtained the synchronization word is received correctly and more than 17 bits of the corresponding 36 bits are wrong, and therefore,

$$P_{\rm fa}^{\rm prop} = (1-P_e)^{16}\cdot\left\{\sum_{k=17}^{36} {}_{36}C_k\,(1-P_e)^{36-k}P_e^k\right\}. \quad (10)$$

IV. NUMERICAL RESULT

A frequency of 600 MHz and v of 10 m/s are also assumed for evaluating $P_{\rm md}$ and $P_{\rm fa}$. Substituting Eqs.(1) and (3) into Eqs. (7) and (8), we obtain $P_{\rm md}$ for the conventional and the TMCC parity method for AWGN and Rayleigh fading. Substituting Eq.(6) into them, we also obtain $P_{\rm md}$ for their subcarrier frequency diversity as shown in Fig. 3. An increase

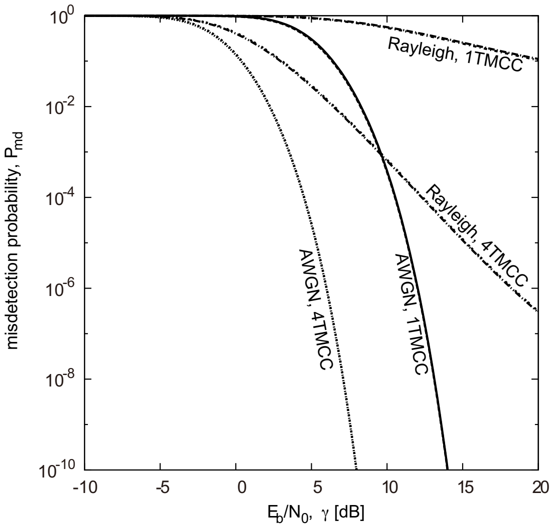

Fig. 3. P_{md} in AWGN and Rayleigh fading environments.

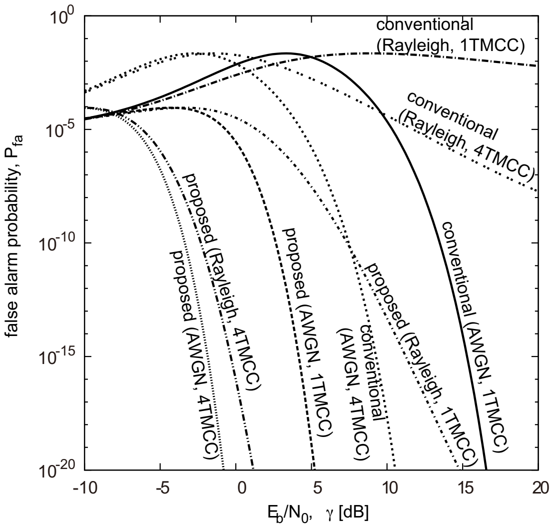

Fig. 4. P_{fa} in AWGN and Rayleigh fading environments.

in γ decreased P_{md}. P_{md} of the TMCC parity method is almost the same as the conventional one, and this is because the probability the synchronization word agrees is dominant over the probability agreeing the corresponding bits. On the other hand, the use of the subcarrier frequency diversity reduced P_{md} for AWGN and Rayleigh.

P_{fa} for AWGN and Rayleigh are also obtained substituting Eqs.(1) and (3) into Eqs.(9) and (10), and are plotted in Fig.4. For a higher γ, both of P_{fa} were small because of the low P_e. On the other hand, for a lower γ, both of P_{fa} were also low, because the synchronization word hardly matched. Therefore, P_{fa} were convex shaped. The subcarrier frequency diversity and the TMCC parity method also decreased P_{fa}.

P_{fa} in Rayleigh fading environment as a function of v is obtained using Eqs.(3), (9), and (10) for evaluating the P_e floor on P_{fa}. The result is plotted in Fig. 5. A decrease in v also decreased P_{fa}, and the TMCC parity method decreased P_{fa} significantly than the conventional method did. The use of subcarrier frequency diversity also reduced P_{fa}, and the TMCC parity method and the subcarrier frequency diversity mutually decreased P_{fa}, and P_{fa} with the combination was lesser than 10^{-40} at a velocity of 100 m/s and it is almost free from false alarm. Supposed power consumption at the decoder and display parts is dominant, the power consumption would also be decreased by this rate.

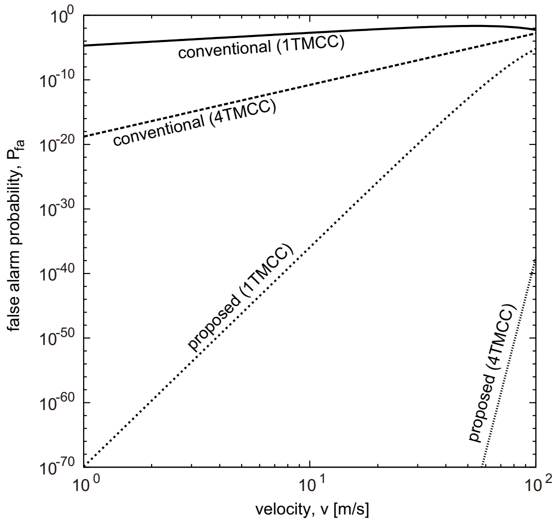

Fig. 5. P_{fa} in mobile environments for sufficient high E_b/N_0

V. CONCLUSION

The method of detecting the emergency wake-up trigger for digital television receivers was proposed. The TMCC parity method and the subcarrier frequency diversity complementary reduced the probabilities of both the false alarm and the misdetection. The subcarrier frequency diversity reduced the misdetection probability the TMCC parity method could not reduce and further reduced the false alarm probability.

ACKNOWLEDGMENT

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