

Repetitive Error Correction Method for Mobile Reception in DARC FM Multiplex Broadcasting Systems

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Abstract—In this paper, we propose a repetitive transmission method for improving the reception performance of VICS (Vehicle Information and Communication System) on DARC (Data Radio channel). DARC is a teletext broadcasting system multiplexed on an existing FM (Frequency Modulation) radio broadcasting. However the reception performance of DARC does not satisfy the demand for VICS application in multipath fading environment. In order to improve the reception performance, this paper proposes a repetitive transmission and a corresponding packet combining method. Numerical results confirm that the proposed method obtains 10 dB gain in terms of required CNR (Carrier-to-Noise Ratio) to achieve PER (Packet Error Rate) of 0.01 in 2-path Rayleigh fading channel.

Index Terms—FM, DARC, VICS, repetitive transmission, packet comparison

I. INTRODUCTION

VICS (Vehicle Information and Communication System) is one of ITS (Intelligent Transport Systems) deployed in Japan and provides road and traffic information to automotive navigation system in real-time by optical beacon, radio beacon, and teletext broadcasting multiplexed on the existing VHF (Very High Frequency) FM (Frequency Modulation) radio broadcasting signal [1]. Of those three transmission methods, FM multiplex broadcasting method is most widely used [2].

FM multiplex telecasting offers information like text and simple images which are related to the contents of FM audio signals. The digital-modulated text and image data signal are multiplexed with the baseband stereo composite signal. The multiplexed signal is applied to FM transmitter. The FM multiplex telecasting system was standardized as DARC (Data Radio Channel) in 1995 [3]. However the reception performance does not satisfy the ITS applications.

DARC provides 6.8 kbps of data rate in total. VICS uses a half of the rate and another half is currently unused. Modeling efficient use of the unused data could improve the reception performance of VICS information.

In this research, a repetitive transmission scheme and its error correction method are proposed in order to satisfy the required quality of VICS data. By the repetitive transmission of VICS data packets, time-diversity gain can be obtained. Besides, an

appropriate selection combining called PC (Packet Comparison) of the duplicated packets further improves the reception performances with combining iterative error corrections of the product code used in DARC.

The rest of this paper is organized as follows. Section II explains DARC based FM multiplex broadcasting system. Section III describes the proposed repetitive packet transmission method and its corresponding error correction method. In Section IV, we evaluate the error rate performances of the proposed method by computer simulation, followed by the concluding remarks in Section V.

II. DARC OVERVIEW

In this section, we briefly introduce the principle of DARC which is currently used for teletext broadcasting. The data signal of DARC is multiplexed on the existing FM radio broadcasting signal.

A. Transmitter and Receiver block diagrams

Figure 1 shows the block diagram of the transmitter and receiver of DARC based FM multiplex broadcasting system. First, the transmitter is explained. In FM broadcasting system, L (Left) and R (Right) channel signal are multiplexed. The L and R channels are converted to sum (L+R) and difference (L-R) signals. The difference (L-R) signal is modulated onto 38 kHz sub-carrier in DSB-SC (Double sideband - suppressed carrier) modulation format. The sum (L+R) signal and modulated difference signal are summed in conjunction with the 19 kHz pilot tone.

Digital data for DARC are modulated in MSK (Minimum Shift Keying) scheme. The amplitude of modulated signal is controlled by level controller according to the amplitude of L-R signal. This scheme is referred to as LMSK (Level-controlled MSK) [4]–[6]. The detail of LMSK scheme will be introduced in section II.C.

LMSK-modulated signal is further summed with the stereo composite signal and applied to FM transmitter. The frequency spectrum of over all multiplexed signal at the input of FM transmitter is illustrated in Fig.2.

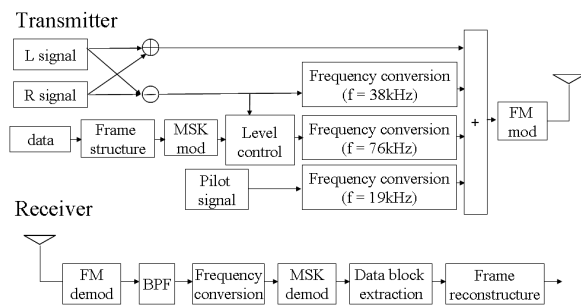


Fig. 1. System model

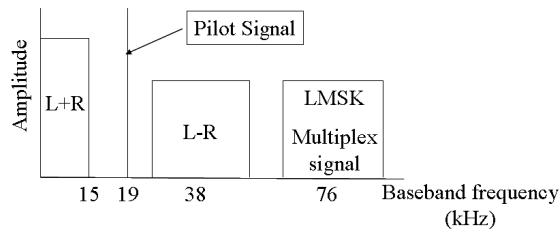


Fig. 2. Composite signal spectrum of FM multiplex broadcasting

At the receiver side, LMSK signal is extracted by BPF (Band Pass Filter) from the received multiplex signal after FM demodulation. The baseband LMSK signal can be obtained by multiplying the corresponding subcarrier whose frequency is fourfold of the pilot signal. In the next step, MSK demodulation is applied to the baseband LMSK signal. Then, using the binary sequence generated by the MSK demodulator, the received frame is reconstructed.

B. Frame Structure

Let's introduce the frame format of DARC. Figure 3 shows the frame structure format. In the frame, the number of raw data is 190-by-176 bits, where 190 is the number of packets and each packet contains 176 bits. For each packet, 14 bits of CRC (Cyclic redundancy Code) is attached for error detection. The resulting 190-bit packet is then coded by (272, 190) shortened difference-set cyclic code. The encoded 272-bit blocks are organized into 190 rows. Each 190-bit column block is further inputted to the (272,190) encoder to generate 82 parity check bits. The generated parity check bits are organized into 272 columns with 82 bit per column. The parity bits in row are viewed as 82 additional blocks with 272 bit per block. Lastly, BIC (Block Identification Code) is added in front of each encoded block to form the DARC packets. At the receiver, frame synchronization can be established by using the BIC.

As shown above, a product code of (272, 190) shortened difference-set cyclic code is adopted as an error correction code in DARC method. This code can correct up to 9 randomly occurred error bits in one coded block. Furthermore it is robust against burst errors. This implies that the code is efficient to improve the performance in multipath fading as well as impulse noise channel [7]. Furthermore, the complexity of decoding circuit can be small.

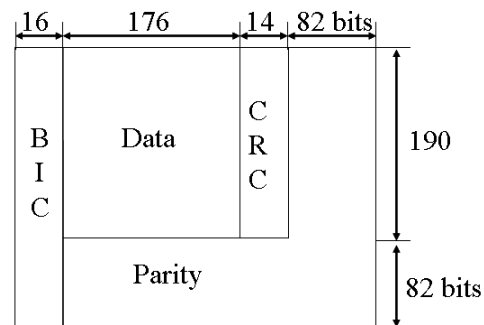


Fig. 3. Frame format of DARC

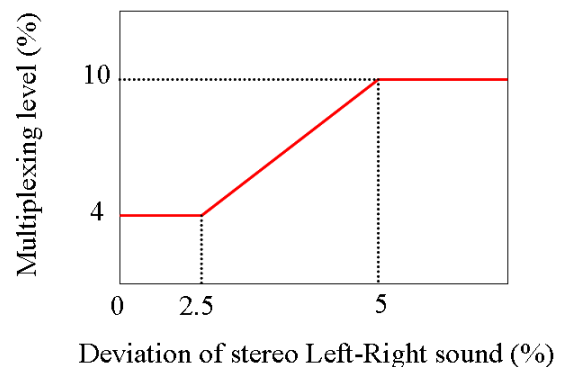


Fig. 4. Level control characteristics

C. Modulation Method

For modulation method, MSK method, which is robust over non-linear system, is adopted in FM multiplex broadcasting [4]. Since too much power or frequency deviation to multiplex data signal causes interference to L-R signal, level control algorithm which changes the level of MSK signal according to the level of L-R signal as shown in Fig. 4 [4], [6]. The modulation scheme combining MSK and the level control is called LMSK. The relationship between the amplitude of L-R signal and multiplex signal is shown in Fig. 4. The amplitude of LMSK signal varies between 3 kHz (4% of multiplex level compared with the maximum frequency deviation) and 7.5 kHz (10 %) according to changing the amplitude of L-R signal between 1.875 kHz (2.5%) and 3.75 kHz (5 %).

III. PROPOSED PACKET TRANSMISSION AND ERROR CORRECTION METHODS

In this section, we propose a repetitive data transmission method and a corresponding error correction technique which combines the received packets with the same transmitted data.

A. Frame Structure of Repetitive Packet Transmission

In the FM multiplex broadcasting system, one frame consists of 190 data packets and each packet consists of 176 data

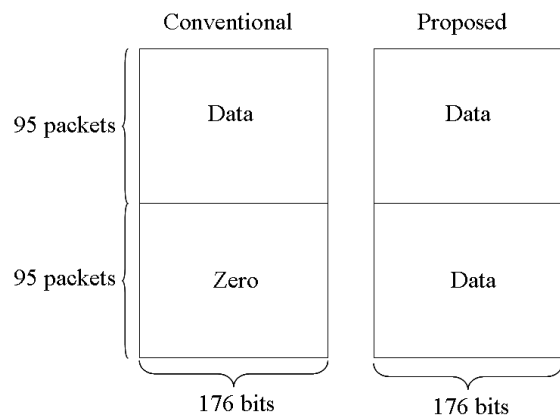


Fig. 5. Data frame structures of conventional and proposed methods.

bits as shown in Fig. 3. In the past, a half of the data packets in a frame was used for text broadcasting of the broadcasting station and the remaining half was for broadcasting VICS data. However, since the text broadcasting service had already finished, the half of the frame currently carries no information, i.e., data of zeros are filled in the half as shown in the left-side of Fig. 5. Even data of zeros spend energy as much as the VICS data, it might be efficient to utilize the half of the frame for improving the reception performance of VICS data.

Thus, we propose a data transmission scheme to utilize the currently unused packets to enhance the reception quality of VICS data packets. The proposed scheme transmits the VICS data packets repetitively, i.e., VICS data are carried by a half of a frame and the same data are carried by another half in the same frame. The frame structure is illustrated in Fig. 5. Due to the time diversity, we can estimate improvement of 3 dB in CNR by the proposed packet transmission. Since the frame structure and the transmitted data in the packets for VICS data are the same as the current use of the frame, the proposed repetitive transmission method can allow backward compatibility.

B. Error Correction for Repetitive Packet Transmission

The repetitive packet transmission scheme transmits the same data of packets twice in different time. After a frame reception, we apply the error correction of (272, 190) code for each packet, or the error correction of horizontal direction. Then, we can determine whether each packet still includes errors or not based on the syndrome which is output from the error corrector. When fading effects are independent in those packets, extracting a data packet without error from the two can improve the packet error rate because of the selection combining. Thus, first we compare the syndromes of corresponding data packets. If both packets are without error or both packets include errors, the packets are remained as they are. If one of two packets transmitting the same data is without error, the erroneous packet is overwritten by the corrected data of the error-free packet. We call the error correction method according to comparing syndromes packet comparison (PC).

TABLE I
SIMULATION PARAMETER

Modulation scheme (audio)	FM method
Modulation scheme (data)	LMSK method
Channel model	AWGN 2-path Rayleigh fading
DUR	15 (dB)
Delay time	2 (μ s)

By PC method, erroneous bits in the packet with residual errors can be corrected, if the other packet is received with good conditions.

Since transmitters apply the product code of (272, 190) codes, we can apply error corrections in vertical direction after performing PC to further improve the ability to correct errors. Moreover, the residual errors can be minimized by repetitively applying horizontal and vertical error corrections.

In the next section, we evaluate the performances of FM multiplex broadcasting system with the proposed repetitive packet transmission and error correction method of PC with the iterative error correction corresponding to the product code.

IV. NUMERICAL EXAMPLES

In this section, we numerically compare the performances of a conventional packet transmission scheme and the proposed method. Since product code of (272, 190) code is applied in the frame structure, error corrections according to (272, 190) code is applicable to both horizontal (row-wise) direction (shown as 'H' in the following) and vertical direction (shown as 'V') at the receiver. In numerical results, we derive appropriate combinations of the error correction methods including H, V, and PC. To show the quality of received signal, we use CNR (Carrier-to-Noise power Ratio) which is defined as the power ratio of multiplexed FM signal to the noise.

For evaluating the BER (Bit Error Rate) and PER (Packet Error Rate) of multiplexed data by computer simulation, we set the simulation parameters shown in Table I. We assume AWGN (Additive White Gaussian Noise) channel and quasi-static 2-path Rayleigh fading channel, where quasi-static means that fading coefficients are unchanged during a packet and that coefficient varies packet-by-packet independently. To show the strength of delayed path comparing with the first arrival path, we use DUR (Desired-to-Undesired signal power Ratio).

BER versus CNR of the conventional error corrections and the proposed method is shown in Fig. 6. The BER performance of the system without error correction is almost the same as that of horizontal error correction once, and error floor appears at around BER of 0.02. Applying the proposed packet combining method after horizontal error correction (H-PC in Fig. 6), the error floor can be reduced to around BER of 10^{-3} . In addition, this error correction achieves the lowest BER performances among all the performances shown in the figure. The improvement might come from the selection combining of

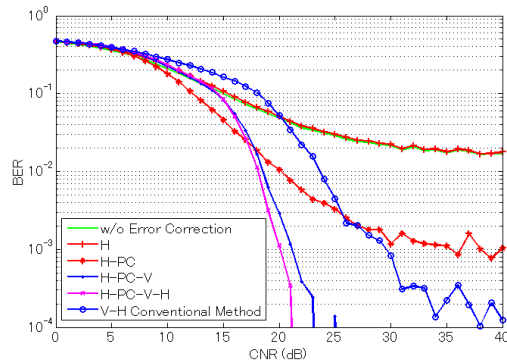


Fig. 6. Bit error rate under certain CNR

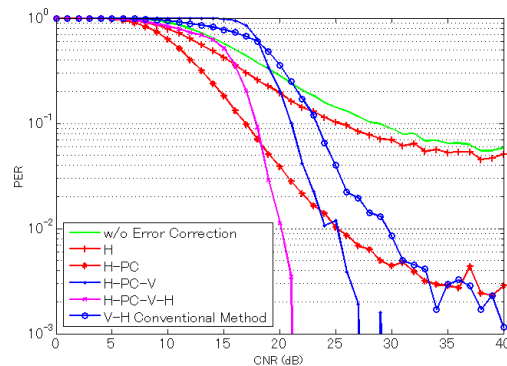


Fig. 7. Packet error rate under certain CNR

error corrected packets in the proposed method. By applying vertical error correction or continuous application of vertical and horizontal error corrections, further improvements can be obtained as we can see from the figure. In particular, the vertical error correction changes the slope of BER performances to steeper. Moreover, the gains obtained by the continuous applications of horizontal and vertical error corrections become less than those obtained by the first application of vertical error correction.

As a counterpart of the proposed method, we also plot the BER performance of the conventional method in which vertical and horizontal error correction is used. When comparing the conventional and proposed methods at $BER = 10^{-3}$, 'H-PC-V' and 'H-PC-V-H' achieve 8 dB and 10 dB gains, respectively. Since the proposed transmission scheme transmits twice data packets as the conventional scheme, it is obvious to obtain 3 dB gain. However, it can be seen that appropriate combinations of selection combining and horizontal and vertical error correction of product code, 5 to 7 dB additional gains can be achieved.

PER versus CNR is illustrated in Fig. 7. The used parameters are the same as those in Fig. 6. When comparing the PER performances of the system without error correction and that with horizontal error correction (H), about 2 dB gain can be obtained by the horizontal error correction due to the

packet based error correction. The horizontal error correction in PER works better than that in BER as we can see from those figures. When we assume that the target PER is 10^{-2} , similar performances can be obtained by 'H-PC' method and 'H-PC-V' method. Besides, about 5 dB gains can be achieved comparing to the case of conventional error corrections (V-H). Although the PER at 10^{-2} of 'H-PC-V' method is the same as 'H-PC' method, the slope of the curve is improved by applying vertical error correction. One reason of the improvement is that the error pattern in vertical direction can see random errors, even the channel model occurs burst errors. In PER performances, applying additional horizontal error correction improves about 5 dB in CNR. However, the improvements by additional vertical and horizontal error corrections to 'H-PC-V-H' method are relatively small; the performances are not shown in the figure. Thus, the proposed method 'H-PC-V-H' is efficient error correction from the view points of PER performance and computational complexity trade-off.

V. CONCLUSION

In this research, we have proposed the repetitive transmission and its error correction method, and then evaluated the error rate of conventional method and the proposed method. From this evaluation, we can find that BER and PER of combination of the proposal method and error correction using the product code are better than the conventional method. The proposed method gives about 10 dB extra gain in terms of BER and PER against CNR. The error rate in low CNR situation can be improved by applying packet comparison after horizontal error correction, obtaining additional gains by applying vertical and horizontal error corrections of the product code.

As future work, we develop reliability based on the information of L-R audio signal. Since the noise characteristics of FM channel is so-called colored noise, we examine decoding method considering the channel characteristics.

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