FIELD EXPERIMENTS ON MH-CODED FACSIMILE DATA TRANSMISSION OVER DIGITAL LAND MOBILE RADIO CHANNELS

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ABSTRACT Modified Huffman (MH)-coded data of an A4-size document was transmitted over a 16 kb/s digital mobile radio channel at a 1.5 GHz carrier frequency. A concatenated time diversity (TD)/forward error correction (FEC) channel coding was applied. The quality of the received image was subjectively evaluated. The results show that the quality of the decoded (received) image can be well estimated by the previous line replacement rate (PLRR) in the MH decoding process.

INTRODUCTION Recently, digital land mobile radio has been attracting much attention because of its capability to transmit voice/data more effectively than current analog FM cellular systems. Land mobile radio channels are characterized by fast multipath fading caused mainly by scattering from buildings surrounding the mobile, and signal transmission performance is severely degraded [1]. Since data transmission requires a very low bit error rate (BER), multipath fading causes a serious problem. Diversity reception [1] and FEC are powerful means to reduce degradation due to multipath fading. In this paper, concatenated TD/FEC channel coding [3] is applied to the transmission of 4.8 kb/s MH-coded data of an A4-size document over a 16 kb/s mobile radio channel. Field experimental results using GMSK [4] modulation at 1.5 GHz carrier frequency are presented. Subjective quality of the received image is evaluated to show that PLRR in the MH-decoding process is a good measure of transmitted image quality.

EXPERIMENTAL SET UP The block diagrams of the base and mobile station systems are shown in Fig. 1. The 4.8 kb/s MH-coded data of an A4-size (approx. 8 in. by 11 1/2 in.) document was encoded by the TD/FEC channel encoder and was 16 kb/s GMSK modulated with $B_bT = 0.25$ (typical for mobile radio applications) at a 1.5 GHz carrier frequency. A two-branch space diversity (SD) receiver using postdetection selection combining (SC) was used. In the diversity receiver, each of the two GMSK signals was bandlimited by a predetection bandpass filter with a 3 dB bandwidth of 16 kHz, the output of the limiter-discriminator with the largest received signal envelope was selected, and applied to a decision device using 2-bit decision feedback equalization [5]. The received 16 kb/s signal and the associated instantaneous received signal envelopes were fed to the channel decoder to obtain the 4.8 kb/s MH-coded data.

The block diagram of the channel coder is shown in Fig. 2. At the encoder, the 4.8 kb/s data to be transmitted is FEC-encoded with BCH(31,21) random error correcting code, bit-interleaved (an interleaving depth of 8 bits is used), and TD-encoded (the resultant 8 kb/s signal and its delayed replica are interlaced with a time separation of 50 msec) to obtain a 16 kb/s signal. At the decoder, both the received a 16 kb/s signal and instantaneous received signal envelopes are fed to the decoder. The received signal envelopes are associated with the two identical 8 kb/s signal streams. The data bit with the largest envelope is selected (postdetection SC for TD reception). After de-interleaving, the 8 kb/s signal is BCH decoded with two-bit error correction. The combination of space and time diversity reception provides four diversity branches, thereby achiving fairly robust data transmission under multipath fading.

The base station was located on top of NTT's R & D Center at Yokosuka, Japan. The test area was a residential area some 2.5 km from the base station. The mobile station was installed in a van, on top of which two $\lambda/4$ whip antennas separated by 1.3 wavelengths were mounted for SD reception. The test document was composed of sentences mixed with Japanese Kanji and Kana characters. The received 4.8 kb/s MH-coded data was recorded for later processing. An MH facsimile receiver was used to obtain hard copies of the received image for later subjective evaluation of the quality.

RESULTS In a previous experiment [6], 4.8 kb/s PN data was transmitted simultaneously using different channel with facsimile transmission channel to estimate the average BER of the received image. In this experiment, however, the average BER was directly determined by comparing the received MH-coded data with the transmitted data and counting the number of bit errors.

Fig. 3 shows the 5-second average BER and 50% BER as a function of the 5-second median signal strength. It is found from the figure that the median signal strength necessary to obtain 50% BER=10^{-3} is about 3 dBμ (-110 dBm at 50 Ω receiver input), which corresponds to 17 dB in the signal energy per bit-to-noise power spectral density ratio (E_b/N_0).

Quality of the received image was subjectively evaluated by 30 laboratory technical members, and the results are represented as mean-opinion-score (MOS) using 1-5 ratings (see Table). The measured MOSs are shown in Figs. 4 and 5 as a function of average of 5-second median signal strengths and average BER, each measured during reception of an A4-size document, respectively. A rating of 3 is obtained at around 5 dBμ and at an average BER of 10^{-3}. Although channel coding and space diversity reception are employed in our experiments, the results shown in Fig. 5 can be applied to the system using single branch reception and no channel coding. Comparison of Figs. 4 and 5 shows that the received signal strengths may not be a good estimate of the quality because of wide spreads of the measured values. Quality can be more accurately estimated using the average BERs than the signal strengths. This is simply because the BER directly affects the MH-decoding process. However, a disadvantage of the BER measurement method is that measurement can not be done simultaneously with reception of the facsimile data.

In MH-decoding, erroneous lines involving more than one bit-error are replaced by the previous correct line. This line replacement is a cause of quality degradation. It was thought likely that the quality was more closely related to the number of previous line replacement than the BER. Noticing this fact, the relationship between PLRR and quality was investigated. Fig. 6 shows the MOS performance as a function of average PLRR measured during reception of an A4-size document. A rating of 3 is acheived at about PLRR=2×10^{-2} (23 lines/A4). The PLRR measurement method is of practical interest in estimating quality because it allows quality assessment while receiving the facsimile data.

At a PLRR of 10^{-1}, quality is below 2. However, if erroneously received lines are retransmitted once and the MH-coded data is reconstructed at the receiver, the resultant PLRR reduces to 10^{-2} from 10^{-1}. This means that quality can be improved to a rating of 3. This suggests the possibility of applicating an ARQ scheme.

CONCLUSIONS Field experiments on 4.8 kb/s MH-coded facsimile data transmissions using TD/FEC channel coding over a 16-kb/s GMSK channel was presented. Through the experiments, it has been shown that quality of the received image can be well estimated from PLRR measurements. The advantage of the PLRR measurement method is that it allows quality assessment while receiving the document.

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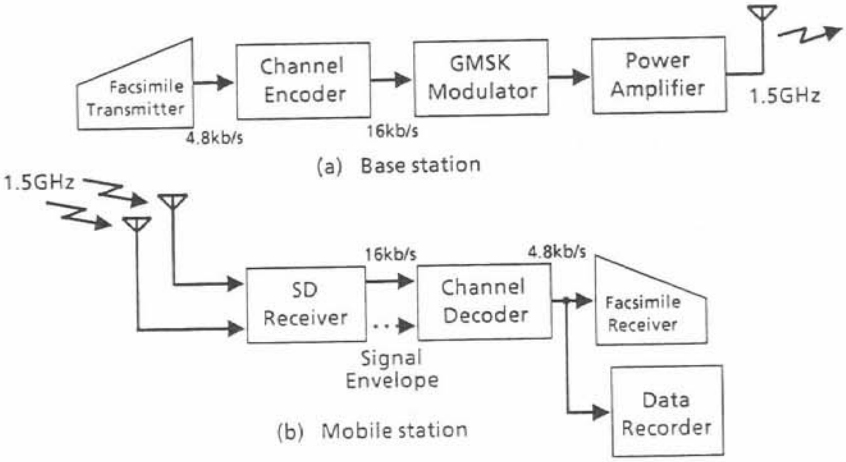

Fig. 1 Block diagram of field experiment system.

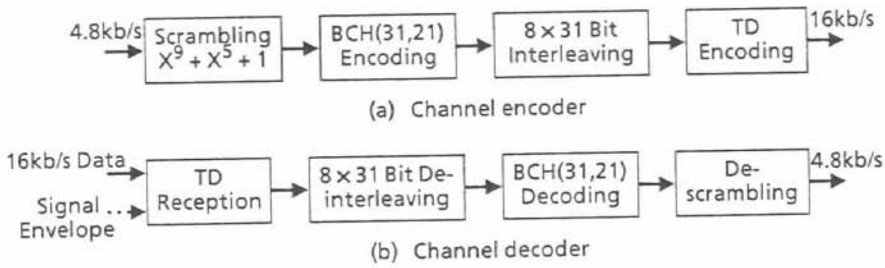

Fig. 2 Block diagram of channel encoder and decoder.

Table

Score	Quality
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

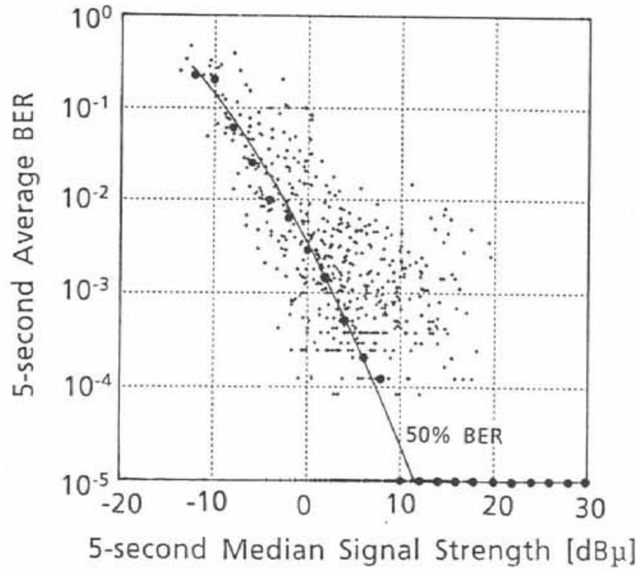

Fig. 3 Average BER performance.

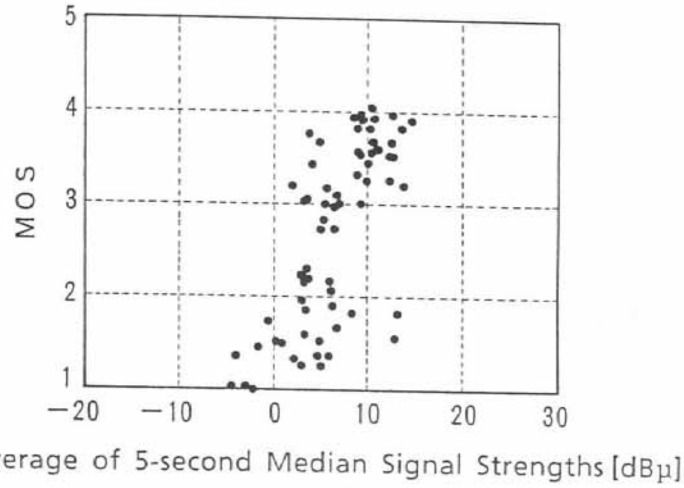

Fig. 4 MOS vs average signal strength measured during reception of an A4-size document.

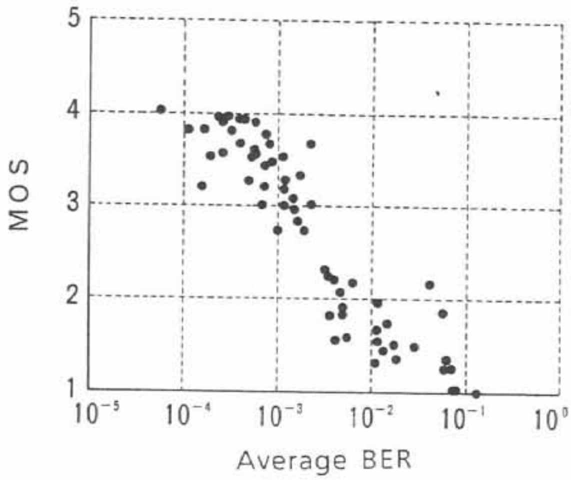

Fig. 5 MOS vs average BER measured during reception of an A4-size document.

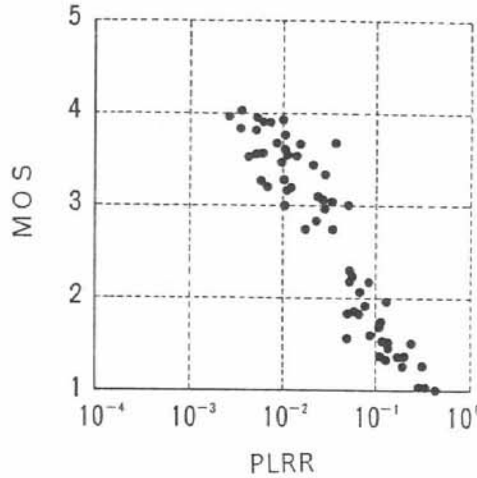

Fig. 6 MOS vs PLRR measured during reception of an A4-size document.