Diversity Selection Based on Decoding Syndrome in Correlated Fading Channels

Martin L. Suen and Shalini Periyalwar
Department of Electrical Engineering
Technical University of Nova Scotia, P.O. Box 1000
Halifax, Nova Scotia, Canada, B3J 2X4
Tel (902) 420-7715, Fax (902) 422-7535, email: shalini@tuns.ca

Abstract

This paper examines a technique for selection diversity using decoding information as the metric for signal quality. The performance is examined in the correlated frequency non-selective fading indoor radio channel. QPSK with coherent detection is used as the modulation scheme. Small BCH block codes of length 7, 15, 31 and 63 are considered.

1. Introduction

In TDMA digital transmission for use in portable indoor radio communications, one of the impairments encountered is correlated slow fading. At low portable speeds typical of slow user mobility in the indoor communications, the frequency and duration of error bursts due to deep fades influence the choice of the Forward Error Correction (FEC) scheme to be used. FEC is effective against Rayleigh fading only when used with interleaving [1][2]. Concatenated coding and interleaving has also been shown to be useful in the mobile radio channel [3]. The problem is that in the presence of deep fades FEC becomes useless without interleaving, and depending on the duration of the fade, interleaving will incur excessive delays.

In such a situation, space diversity is an effective method for combating Rayleigh fading [4] assuming that the received signal at each antenna is subject to uncorrelated fades. The space available for antenna separation is limited so that the fading signals are usually correlated. It was reported in [5] that postdetection selection diversity is still an effective measure against correlated Rayleigh fading. Often, selection diversity is accomplished using the received signal strength as a quality measure. However, selection diversity based on signal strength cannot reveal the quality of the received signal, because the measured power could be contributed mostly by interference (cochannel and adjacent channel) and noise. FEC decoding provides an alternative measure of signal quality aside from signal strength. In recent work [6] on diversity selection based on syndrome detection using a BCH(31,21,5) code, significant improvement in the performance was observed over coding without diversity in the uncorrelated frequency selective fading channel.

The purpose of this work is to study the effect of post-detection selection diversity combining using the decoding syndrome of BCH codes in correlated frequency non-selective fading channels, using computer simulation.

The content of this paper will be as follows. Section 2 will describe the syndrome selection algorithm and the computer simulation. The result of the simulation will be presented in Section 3 and some conclusions will be made in Section 4.

2. System Description

A. System Model

The system assumes an indoor TDMA radio link, with a data rate of 500 Kbit/sec and a carrier frequency of 1.3 GHz. Delay spread is assumed to be in the order of nanoseconds and thereby negligible. The transmitter consists of binary signal generator, a (n,k) BCH encoder and a QPSK modulator.

The channel model multiplies the transmitted symbol with a fading sample and adds AWGN. Correlated fading is generated by SIRCIM [7], an indoor channel simulator, over a course of one meter using a hand-held receiver. SIRCIM is used to generate frequency non-selective (flat) fades under a variety of indoor conditions. The variable conditions used are vehicle speeds, room environment and line-of-sight (LOS). Vehicle speeds are chosen to be 0.1, 1.0, and 10.0 m/sec. Three different room conditions SOFT, OPEN, and HARD partitioning are employed. LOS is taken to be either 0 or 100%. The results are averaged over several fades generated by using combinations of the above conditions. Space diversity generally requires that the antennas are spaced far enough apart that the received paths are uncorrelated. In the indoor environment, working under limited space and in areas without great terrain differences, correlated fading should be expected, and is considered the worst case scenario. Samples of the fading process generated by SIRCIM are shown in Fig. 1.

The receiver consists of a demodulator, decoder, channel selector and a bit error rate (BER) meter. The received signals are coherently detected with hard-decision decoding using the Berlekamp algorithm [8].

B. Diversity Selection Based on Error Detection

At the receiver, the Syndrome Selection Diversity Combining (SSDC) algorithm behaves more like switched combining; given two diversity branches, one will be selected and remains selected until the syndrome detects an error or a value other than zero. Once a syndrome error has occurred, then all other branches are examined for a syndrome without errors. If no branches can be found without a syndrome error then the selection algorithm searches for a branch that has been decoded properly. In the case of a tie where more that one branch has been decoded properly, or the opposite situation where no branches are decoded properly, the original branch is retained.

In the next section results of the performance of the SSDC scheme are presented as plots of BER vs. SNR, for various BCH codes. The SSDC scheme is compared with uncoded QPSK modulation with symbol by symbol selection diversity based on signal strength (diversity only), and with BCH coded QPSK modulation with selection diversity, denoted as SDC (Signal strength Diversity Combining).

3. Results

Figures 2 to 5 present the BER vs. SNR curves for various BCH coded QPSK systems. In the correlated fading channel BCH coding with hard decision decoding offers gains over uncoded modulation only at high SNRs. The results are plotted for bit SNR values, and the loss in information rate should be factored in while comparing the uncoded and BCH coded schemes.

In Figure 2 the uncoded QPSK system with no diversity selection is shown for comparison. For the (7,4) and (15,11) codes considered, the SSDC scheme shows no performance improvements over uncoded modulation.

Figure 3 shows a comparison between SSDC and SDC. for the $n = 31$ block code. the BCH codes offer viable gains at high SNRs. The performance of the SSDC scheme is better than that of SDC (diversity with coding), when the code rate is small. Similar observations can be made with $n = 63$ codes shown in Figure 4 and 5. However, one should consider that using SSDC diversity selection can be made without losing too much efficiency.

In the correlated fading channel BCH coding with hard decision decoding offers gains over uncoded modulation at high SNRs. For all the codes considered, SSDC performs nearly as well as Signal Strength Diversity Combining (SDC), but does not show significant gains or improvement over SDC at low SNRs. At high SNRs and for low rate codes, a small performance improvement is observed.

4. Conclusion

Syndrome selection diversity combining has been examined in the indoor Rayleigh fading environment. From the simulation study of BCH coded QPSK with hard decision decoding, it is observed that SSDC can be a possible alternative to signal strength diversity combining.

Although, SSDC does not show significant gains or improvement over SDC, we must take into consideration the simplicity of this new scheme. An envelope detector circuit will not be required to determine the signal strength. Further, switching between channels will be minimized, since switching will be initiated by the detection of an error in the syndrome. Finally, signal strength is no longer used as the criterion for channel selection, and the SSDC algorithm should perform very well in a channel with interference.

5. Acknowledgments

This research was supported by funding from the Burchill Communication Research Group.

6. References

[1] L. F. Chang and S. Ariyavisitakul, "Performance of Convolutional Codes with Interleaving in the Interference Limited Rayleigh Fading Channel," *IEEE Veh. Technol. Conf. Rec.*, pp 812-816 May 1991.

[2] J. Hagenauer and E. Lutz, "Forward Error Correction Coding for Fading Compensation in Mobile Satellite Channel," *IEEE Journal on Sel. Areas in Comm.*, vol. 5, no 2 pp 215-224, Feb. 1987.

[3] X. Jin and S.S Periyalwar "Performance of Intercode Interleaving in the Indoor Portable Radio Channel," *2nd International Conf. on Univ. Personal Comm. ICUPC '93*, Ottawa, ON, Oct 12-15, 1993, pp 453-457.

[4] W. C. Y. Lee, *Mobile Communications Engineering*, New York, McGraw-Hill, 1982.

[5] F. Adachi, K. Ohno and M Ikura, "Postdetection Selection Diversity Reception with Correlated, Unequal Average Power Rayleigh Fading Signals for Π/4-Shifted QDPSK Mobile Radio," *IEEE Tran. on Vehicular Technology*, vol. 41, no. 2, pp 199-210, May 1992.

[6] L. F. Chang and J. C. Chuang, "Diversity Selection Using Coding in a Portable Radio Communication Channel with Frequency Selective Fading," *IEEE Journal on Selected Areas in Communications*, vol. 7, no. 1, pp 89-98, Jan 1989.

[7] T. S. Rappaport, S. Y. Seidel, P. M. Koushik and S. L. McCulley, *A User Manual for SIRCIM: Simulation of Indoor Radio Channel Impulse Response Models, Version 2.0*, Virginia, Virginia Tech Intellectual Properties, 1992.

[8] S. Lin and J.D. Costello, *Error Control Coding: Fundamentals and Application*, New Jersey, Prentice-Hall, 1994.

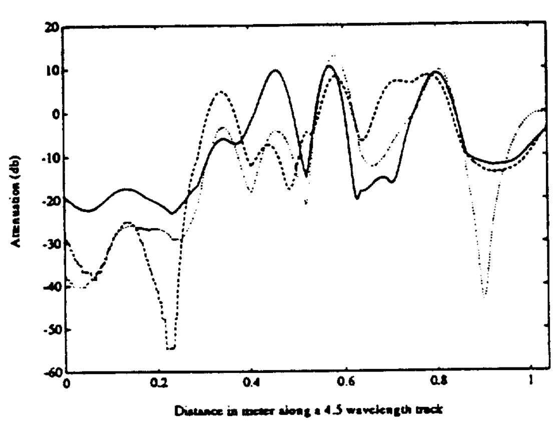

Figure 1. Correlated Fading Samples

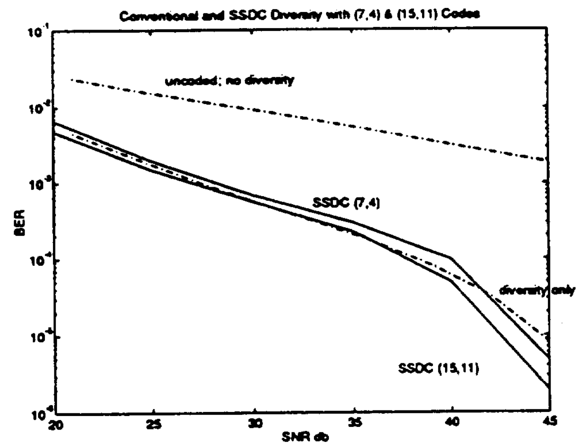

Figure 2. Average BER vs. SNR for (7,4) & (15,11) code using SSDC scheme

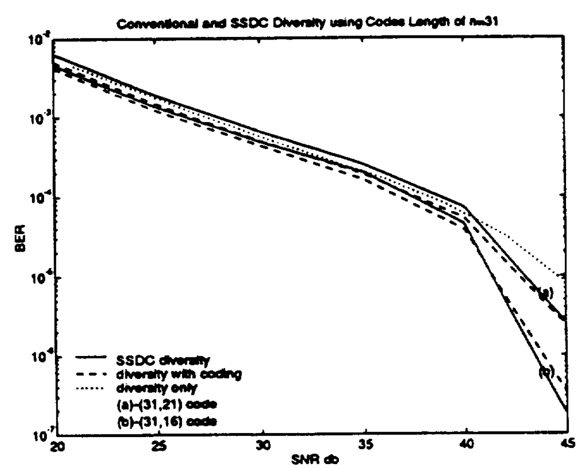

Figure 3. Average BER vs. SNR with SSDC and BCH(31,k)codes

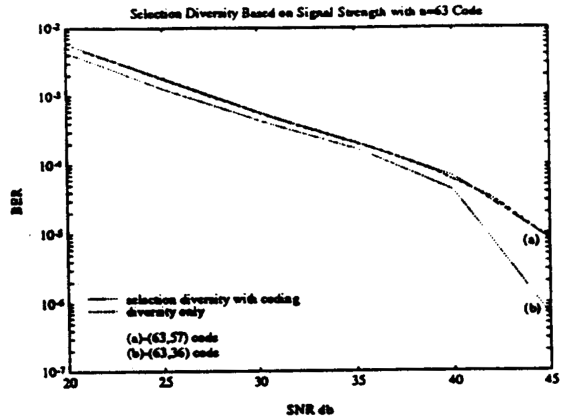

Figure 4. Average BER vs SNR using signal strength diversity and BCH(63,k) codes.

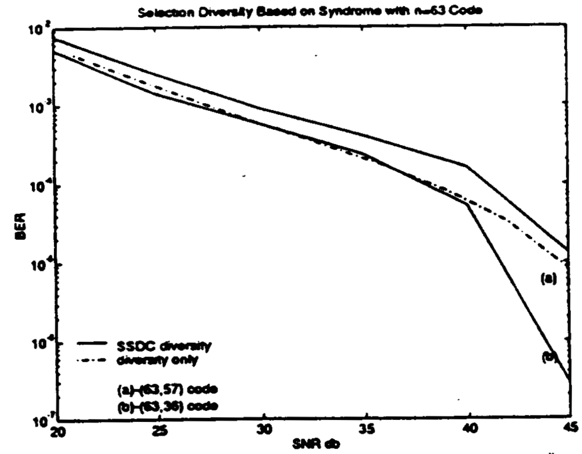

Figure 5. Average BER vs SNR using BCH(63,k) codes with SSDC