Superposed Band Detection Based on Error Probability Using Initial Likelihood Masking

Tomoaki Ohtsuki†, Genji Hayashi†, Jun Mashino‡, Takatoshi Sugiyama‡
† Department of Information and Computer Science, Keio University
3-14-1, Hiyoshi, Kohoku-ku, Yokohama, 223-8522 Japan
‡NTT Access Network Service Systems Laboratories
Yokosuka, 239-0847 Japan
E-mail:†ohtsuki@ics.keio.ac.jp

***Abstract*—Superposed multicarrier transmission scheme is known to improve frequency utilization efficiency where several systems share spectrum without any spectrum spreading techniques. In superposed multicarrier transmission scheme forward error correction (FEC) coding is applied over subcarriers so that the effects of interference caused by superposition is mitigated by interleaving effects. When the interference power is large, the effects of FEC become smaller particularly owing to the mis-setting of initial log likelihood ratio (LLR). To solve this problem, FEC metric masking is proposed where initial LLRs for superposed subcarriers are replaced by neutral value in the receiver followed by decoding. This technique is effective, however, it needs the information about superposed frequency band. In this paper we propose a scheme to detect superposed band by using FEC metric masking. In the proposed scheme, the subcarriers where FEC metric masking is applied are changed and packet error rate (PER) is measured. When the FEC metric masking is applied to the superposed subcarriers, PER is minimized. Based on the change of PER, we can detect the superposed band. We evaluate the proposed scheme by computer simulation and show that it can detect the superposed band with high probability.**

I. Introduction

Owing to explosive increase of data traffic in wireless communications, the shortfall in frequency bandwidth becomes a pressing problem in wireless communications. Various kinds of techniques have been proposed, such as powerful forward error correction (FEC) coding, such as Turbo codes and LDPC (low-density parity-check) codes, multiple-input multiple-output (MIMO), and so on [1]. Those techniques are very efficient to increase frequency utilization efficiency, yet we still need to improve frequency utilization efficiency.

When several independent wireless systems exist, one way to improve frequency utilization efficiency is allocating them in sharing frequency bandwidth allowing spectra overlap [2]. Spectrum sharing scheme makes the overall frequency bandwidth narrower than traditional spectrum allocation that in general needs guard band to avoid interference among them. Spectrum sharing scheme, of course, suffers from interference from spectra overlap. Thus, to improve frequency utilization efficiency, it needs to reduce the effects of the interference. In the environment where several independent wireless systems exist, we cannot expect the exchange of information among them. Therefore, spectrum sharing scheme is required to reduce the effects of interference by signal processing completed in the receiver. The approach of improving the receiver is more advantageous than controlling transmitters, as it does not impact any existing wireless system standards, or air interfaces. In those kinds of processing, it is desired to suppress interference against arbitrary signals from any systems.

Superposed multicarrier transmission scheme is known as one of spectrum sharing schemes that can improve frequency utilization efficiency without any spectrum spreading techniques [3]. In superposed multicarrier transmission scheme FEC coding is applied over subcarriers so that the effects of interference caused by superposition is mitigated by interleaving effects. When the interference power is large, the effects of FEC become smaller particularly owing to the mis-setting of initial log likelihood ratio (LLR). To solve this problem, FEC metric masking is proposed where initial LLRs for superposed subcarriers are replaced by neutral value in the receiver followed by decoding [4]. This technique is effective to reduce the effects of interference by superposing by offset. The technique is attractive, because it depends on neither the number of interferers nor the signaling of the superposed interference systems. However, the initial likelihood masking requires the knowledge of superposed band, which is sometimes difficult to realize.

In this paper we propose a scheme to detect superposed band by using FEC metric masking. In the proposed scheme, the subcarriers where FEC metric masking is applied are changed and packet error rate (PER) is measured. When the FEC metric masking is applied to the superposed subcarriers, PER is minimized. Based on the change of PER, we can detect the superposed band. We evaluate the proposed scheme by computer simulation and show that it can detect the superposed band with high probability.

II. Superposed Multicarrier Transmission

Superposed multicarrier transmission superposes some of the subcarriers of multiple signals. Fig. 1 shows an example of spectrum allocation in the superposed multicarrier transmission scheme for the case of two signals superposition. In conventional spectrum allocation two signals are located with guard band between them to avoid interference. In the

978-1-4673-0990-5/12/$31.00 ©2012 IEEE

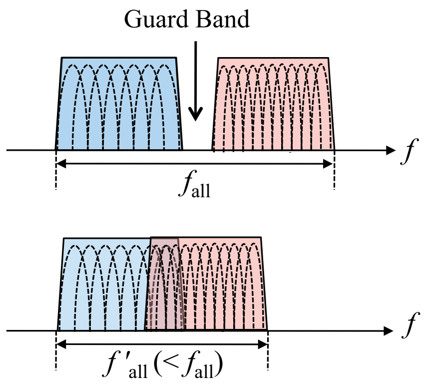

Fig. 1. Spectrum Allocation in Superposed Multicarrier Transmission

superposed multicarrier transmission scheme some of the subcarriers of two signals are superposed so that the total frequency bandwidth occupied becomes narrower. Hence we can achieve higher frequency utilization efficiency if the throughput degradation due to interference of superposed subcarriers is offset. To eliminate the effects of interference of superposed subcarriers, superposed multicarrier transmission uses FEC and subcarrier interleaving. However, when the received D/U (Desired to Undesired power ratio) is as low as 0 dB, using FEC and subcarrier interleaving cannot remove the effects of interference of superposed subcarrier perfectly [4]. This is owing to the wrong setting of initial likelihood for the input of the FEC decoder in the receiver. The initial likelihood for the input of the FEC decoder is determined by CINR (Carrier to Interference and Noise Ratio) per subcarrier. CINR on a superposed subcarrier is very low if the received D/U is low as mentioned above, so the accuracy of channel estimation and CINR estimation for the interfered subcarriers is largely degraded. As a result, inaccurate initial likelihoods are assigned to bits on unreliable subcarriers and thus error correction performance is degraded. To reduce the bad effects of wrong setting of initial likelihoods assigned to bits on superposed subcarriers, the initial likelihood masking technique was proposed in [4], which will be explained in the next section.

III. Initial Likelihood Masking

As mentioned above, in the superposed multicarrier transmission, when the received D/U is as low as 0 dB, using FEC and subcarrier interleaving cannot remove the effects of interference of superposed subcarriers perfectly owing to the wrong setting of initial likelihood for the input of the FEC decoder in the receiver. To suppress the effects of interference of superposed subcarriers with practical implementation and without knowledge of interference's signaling, initial likelihood masking, also referred to as FEC metric masking, was proposed in [4]. Fig. 2 shows the concept of initial likelihood masking. It replaces the metrics of the subcarriers in the superposed band with neutral value to lower their reliability. The main idea is that it is better not to use unreliable initial

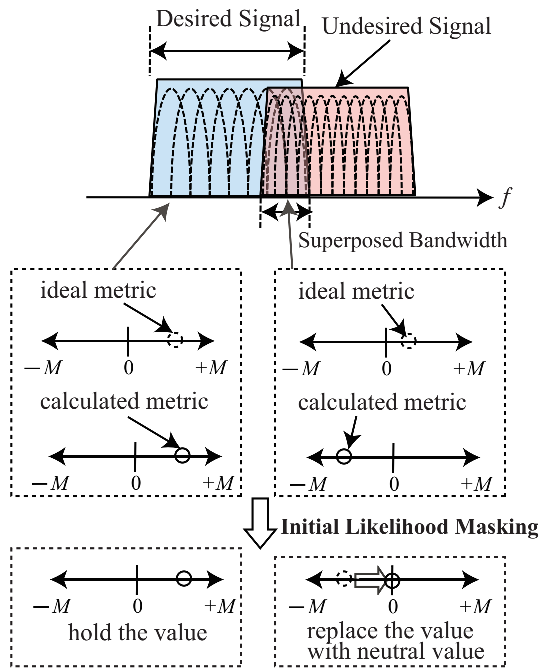

Fig. 2. Initial Likelihood Masking

information obtained at superposed subcarriers but compensate the total performance by using the reliable initial information obtained at non-superposed subcarriers. If the initial log-likelihood value varies between $-M$ to $+M$, the neutral value is zero. On the other hand, it uses the calculated metric values of subcarriers outside the superposed band. It is shown that the technique can improve frequency utilization efficiency of superposed multicarrier transmission.

The technique is attractive, because it depends on neither the number of interferers nor the signaling of the superposed interference systems. However, the initial likelihood masking requires the knowledge of superposed band, which is sometimes difficult to realize, such as in the existence of cognitive systems.

IV. Proposed Interference Detection

Initial likelihood masking is an effective technique to suppress the effects of interference of superposed subcarriers with practical implementation and without knowledge of interference's signaling. However, it requires the knowledge of superposed band. If we change transmission so as to estimate the superposed band, such as stopping transmission periodically for estimation, it is not difficult to estimate it. However, it is not easy for some systems to change signaling. In addition it may result in decrease of throughput. Thus, it is required to estimate superposed band without changing transmission scheme, that is, receiver-based technique. In this paper we propose a superposed band detection technique based on error probability using initial likelihood masking. Fig. 3 shows the block diagram of the proposed scheme. The proposed scheme is based on the following idea: If we

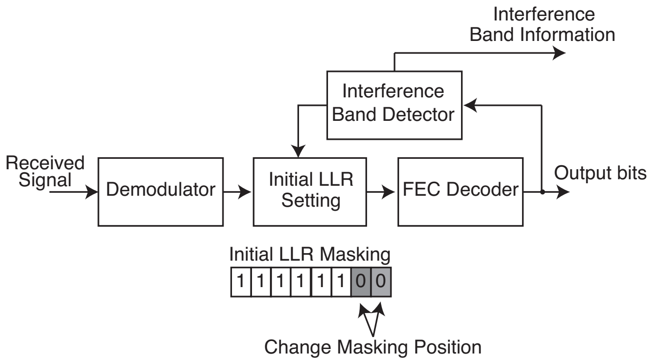

Fig. 3. Block diagram for proposed interference detection scheme

TABLE I
SIMULATION PARAMETERS

1st Modulation	QPSK
2nd Modulation	OFDM (64 subcarriers)
OFDM Symbol Duration	4.0 μs
FEC	Turbo Code
FEC Coding Rate	1/2
Packet	10 OFDM symbols
Channel Estimation	Ideal
Channel Model	Multi-path Rayleigh fading
Number of Multipaths	5
Power Delay Profile	1 dB Exponential Decaying Model

apply the initial likelihood masking to all the superposed band accurately, we can expect that the error rate performance becomes better than that when we apply inaccurately, that is, to some non-superposed subcarriers. We confirmed that this is true by computer simulation, which will be shown in the following section. In the proposed technique we observe the change of error rate performance by changing the bandwidth to apply the initial likelihood masking. The bandwidth that we can obtain the lowest error rate is declared as a superposed one. The proposed technique may require some latency, however, it can be realized only by signal processing at the receiver. It is also attractive, because it depends on neither the number of interferers nor the signaling of the superposed interference systems.

V. EVALUATION

TABLE 1 lists major parameters used for the computer simulation performed. In this paper two signals conform to same parameters to simplify the evaluation. Note that the proposed technique has no need to specify the signaling scheme for any interferer. Note also that there is no need of synchronization between superposed signals. Both are true for the superposed multicarrier transmission scheme itself as well [3][4].

A. Packet error rate versus the number of subcarriers that initial likelihood masking is applied

Figs. 4–8 show PER versus the number of subcarriers that initial likelihood masking is applied. We can see that with E_b/N_0 = 15 dB, D/U = 0, –3 dB, and the number of superposed subcarriers is smaller than 8, PER becomes the best when the number of subcarriers that initial likelihood masking is applied is equal to that of superposed subcarriers. Therefore, based on the change of PER performance by changing the number of subcarriers that initial likelihood masking is applied, we can detect the superposed band. Note that, however, we cannot always detect the superposed band, such as when E_b/N_0 is low and when interference power is small compared to signal power (large D/U). For instance, as shown in Fig. 7, we cannot detect the superposed band because of low E_b/N_0 when E_b/N_0 = 5 dB and D/U = 0 dB. Note also that, as shown in Fig. 8, even when $E_b/N_0 = 15$ dB, we cannot detect the superposed band correctly because of a large number of superposed subcarriers, compared to that of non-superposed ones.

The detection performance depends on several parameters, E_b/N_0, D/U, the number of superposed subcarriers, Doppler frequency, averaging period for evaluation of PER, and so on. We evaluate the detection rate for some parameters in the following subsection.

B. Detection rate versus averaging period

Figs. 9–14 show the detection rate of the superposed band versus averaging period for calculating PER for several parameters. We can see that the proposed scheme can detect the superposed band with high probability in most cases, though it depends on several parameters: When D/U $= -3$ dB, we can detect the superposed band with probability almost 100 % with averaging period of 10 ms or shorter, depending on other parameters. When D/U = 0 dB, $E_b/N_0 = 15$ dB, and the number of superposed subcarriers is 7, the detection rate becomes lower. Those findings hold for Doppler frequency of 30, 100, and 200 Hz. We can also see that the detection rate for higher Doppler frequency is often higher than that for the

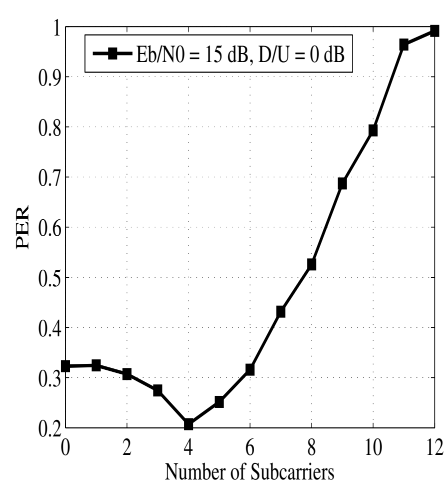

Fig. 4. Packet error rate versus the number of subcarriers that initial likelihood masking is applied : $E_b/N_0 = 15$ dB, D/U = 0 dB, the number of superposed subcarriers = 4

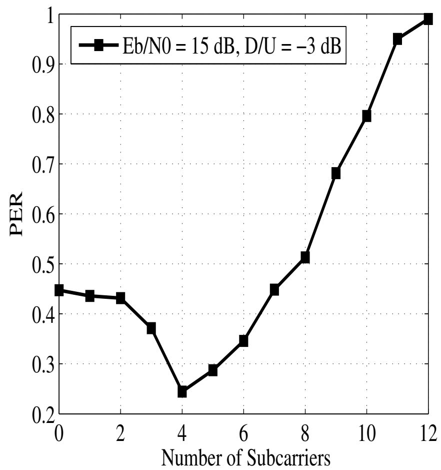

Fig. 5. Packet error rate versus the number of subcarriers that initial likelihood masking is applied : $E_b/N_0 = 15$, D/U = –3 dB, the number of superposed subcarriers = 4

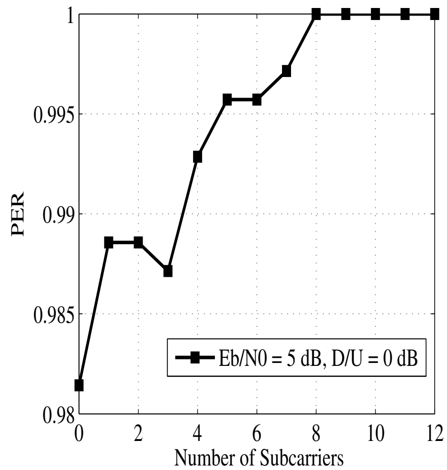

Fig. 7. Packet error rate versus the number of subcarriers that initial likelihood masking is applied : $E_b/N_0 = 5$ dB, D/U = 0 dB, the number of superposed subcarriers = 3

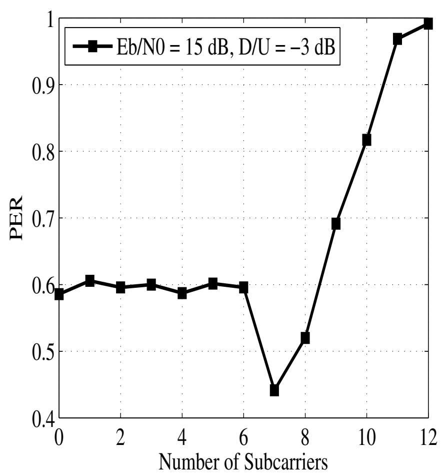

Fig. 6. Packet error rate versus the number of subcarriers that initial likelihood masking is applied : $E_b/N_0 = 15$ dB, D/U = –3 dB, the number of superposed subcarriers = 7

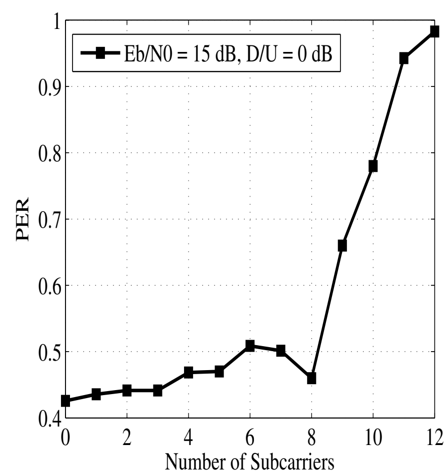

Fig. 8. Packet error rate versus the number of subcarriers that initial likelihood masking is applied : $E_b/N_0 = 15$ dB, D/U = 0 dB, the number of superposed subcarriers = 8

lower one. This is owing to the fact that the detection rate depends on not PER itself but the change of PER. Although not all the data are shown in the paper, we confirmed that the change of PER by changing the subcarriers that the initial LLR masking is applied is often larger for higher Doppler frequency than that for lower one, of course also depending on other parameters.

With averaging period of 10 ms, the proposed scheme can detect the superposed band with about 100 %, though depending on some parameters. Therefore, the proposed scheme is effective for detection of the superposed band only with receiver signal processing in many cases.

VI. Conclusions

Superposed multicarrier transmission scheme is effective to improve frequency utilization efficiency where several systems share spectrum without any spectrum spreading techniques, if we can eliminate the interference from the superposed band. FEC metric masking is one solution to reduce the effects of the interference from the superposed band, though it needs knowledge of superposed band. In this paper we present a scheme to detect superposed band by using FEC metric masking. In the proposed scheme, the subcarriers where FEC metric masking is applied are changed and PER is measured. When the FEC metric masking is applied to the superposed subcarriers, PER is minimized. Based on the change of PER, we can detect the superposed band. Through computer simulation, we showed that it can detect the superposed band in most cases, though it depends on several parameters. The drawback of the proposed scheme is latency, because it needs decoding several times. The latency depends on FEC and hardware. Depending on the requirements for latency and hardware, we need to use

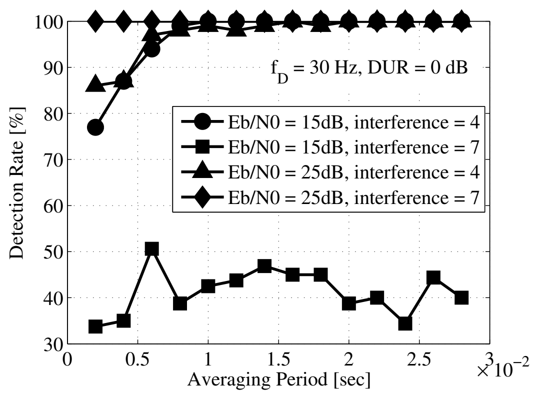

Fig. 9. Detection rate versus averaging period : $f_D = 30$ Hz, D/U $= 0$ dB

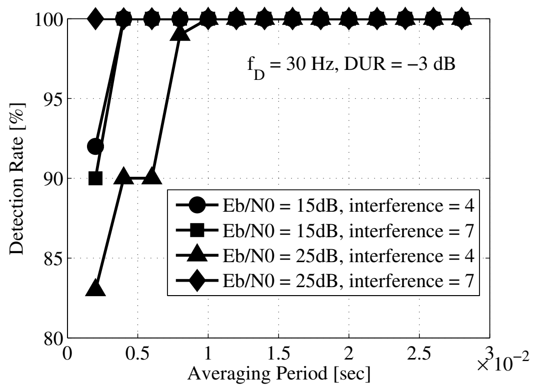

Fig. 10. Detection rate versus averaging period : $f_D = 30$ Hz, D/U $= -3$ dB

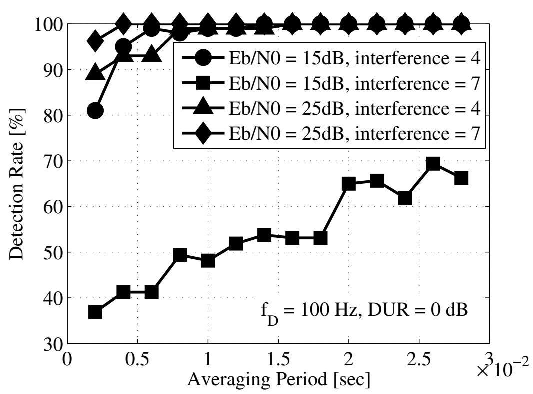

Fig. 11. Detection rate versus averaging period : $f_D = 100$ Hz, D/U $= 0$ dB

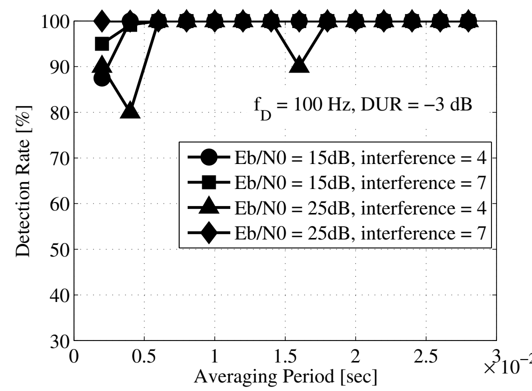

Fig. 12. Detection rate versus averaging period : $f_D = 100$ Hz, D/U $= -3$ dB

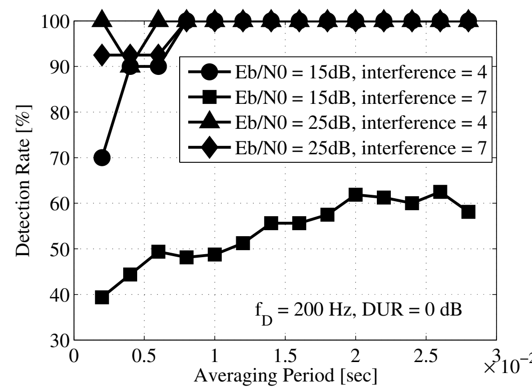

Fig. 13. Detection rate versus averaging period : $f_D = 200$ Hz, D/U $= 0$ dB

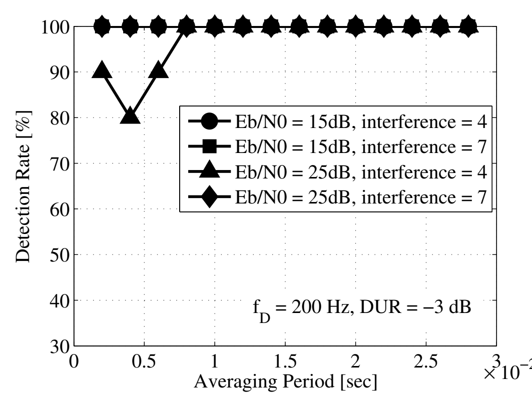

Fig. 14. Detection rate versus averaging period : $f_D = 200$ Hz, D/U $= -3$ dB

appropriate parameters in the proposed scheme.

References

[1] A. Goldsmith, *Wireless Communications*, Cambridge University Press, 2005

[2] J. M. Peha, “Approaches to Spectrum Sharing,” IEEE Commun. Mag., pp. 10–12, Feb. 2005

[3] T. Sugiyama, H. Kazama, M. Morikura, S. Kubota, and S. Kato, “A Frequency Utilization Efficiency Improvement on Superposed SSMAQPSK Signal Transmission over High Speed QPSK Signals in Nonlinear Channels,” IEICE Trans. Commun., Vol.E76–B, No.5, pp. 480–487, May 1993

[4] J. Mashino and T. Sugiyama, “Total Frequency Utilization Efficiency Improvement by Superposed Multicarrier Transmission Scheme,” IEEE International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC2009), Tokyo, Japan, pp. 1677–1681, Sep. 2009