Adaptive Bandwidth Control for Multi-Band OFDM Transmission with Spectrum Sharing

Yoshiki Inuzuka\textsuperscript{1a)}, Shigeru Tomisato\textsuperscript{1, 2}, Kazuhiro Uehara\textsuperscript{1}, Satoru Shimizu\textsuperscript{2}, and Yoshinori Suzuki\textsuperscript{2}

\textsuperscript{1}Graduate School of Natural Science and Technology, Okayama University
3-1-1 Tsushima-Naka, Kita-ku, Okayama-shi, Okayama, 700-8530 Japan
\textsuperscript{2}Advanced Telecommunications Research Institute International
2-2-2 Hikaridai, Keihanna Science City, Kyoto, 619-0288 Japan

a) inuzuka@s.okayama-u.ac.jp

Abstract: This paper proposes an adaptive bandwidth control method in a transmitter for multi-band OFDM transmission with spectrum sharing. The proposed method controls the bandwidth used by a multi-band system to reduce out-of-band distortion noise which interferes to other spectrum sharing systems. In addition, the method uses clipping followed by in-band and out-of-band filtering to satisfy required interference power conditions on other system bands. The evaluation results by computer simulations show that adaptive band selection in the proposed bandwidth control can reduce out-of-band distortion noise power so that the required conditions can be satisfied in other spectrum sharing systems.

Keywords: spectrum sharing, multi-band system, out-of-band noise

Classification: Wireless communication technologies

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1 Introduction
Spectrum sharing is one of promising technologies to increase the capacity of whole network, and multi-band signal transmission which simultaneously uses plural frequency bands is an effective technology to realize flexible and efficient frequency band use in wireless communication systems. On the other hand, OFDM transmission which is very effective in broadband transmission in multi-path fading channels is widely used in wireless systems while it generates excessive peak power which causes in-band and out-of-band noise by non-linear distortion of a transmission power amplifier. In addition, multi-band simultaneous use causes serious distortion noise by inter-modulation distortion. Therefore, effective in-band and out-of-band noise reduction for multi-band transmission have been studied [1].

This letter proposes an adaptive bandwidth control method in a transmitter for multi-band OFDM transmission with spectrum sharing. The proposed method controls the bandwidth of frequency bands used by a multi-band system to reduce out-of-band distortion noise which interferes to other systems shared the same frequency bands. The bands applying bandwidth control are adaptively selected among all usable bands to effectively reduce interference according to the bands used by an interfered system. The method also employs clipping followed by in-band and out-of-band filtering to satisfy required interference power conditions on interfered system bands. This letter clarifies the effect of the proposed adaptive bandwidth control by computer simulations.

2 System model and bandwidth control
Fig. 1 shows the system model and the proposed bandwidth control method in this letter. Multi-band and other wireless systems with OFDM transmission shares the same frequency bands as shown in Fig. 1(a). The multi-band system simultaneously utilizes three bands of B1, B2, and B3. This multi-band simultaneous use causes serious out-of-band noise by inter-modulation distortion, and noise power on adjacent and third inter-modulation (IM3) bands becomes larger. Such out-of-band noise interferes to spectrum sharing systems. When the received power of the multi-band system is extremely larger than that of an interfered spectrum sharing system, the influence of the out-of-band noise cannot be ignored. In this letter, two cases are considered where an interfered system is assigned on the adjacent or IM3 band as shown in Fig. 1(a).

Fig. 1(b) illustrates adaptive bandwidth control of the proposed method to reduce out-of-band noise in a multi-band system which narrows used bands. The bands applying bandwidth control are adaptively selected among all usable bands to effectively reduce the noise on the interfered system bands. In addition, because the method yields unused bands in usable bands, it generates out-of-band noise reduction signals on the unused bands by iterative clipping and filtering [2][3].

Fig. 1(c) shows an OFDM transmitter with the proposed method for a multi-band system. OFDM signals assigned to multiple frequency bands by adaptive bandwidth control are generated by IFFT processing. After the processing, clipping followed by in-band and out-of-band filtering is performed to
reduce out-of-band noise. Fig. 1(d) shows the detection of peak power components exceeding the set clipping level in OFDM signals by clipping. These detected peak power components are transformed into in-band and out-of-band clipping noise of the frequency domain by FFT. In-band and out-of-band filtering removes the noise on used and outside bands, and only the components on unused bands remain as shown in Fig. 1(e). The clipping and filtering are iteratively performed to accurately generate out-of-band noise reduction signals. These filtered signals are added to the narrowed multi-band OFDM signals by bandwidth control, and out-of-band noise are reduced on the bands used by the interfered system.

3 Evaluation results

Computer simulations were conducted to clarify the effect of the proposed adaptive bandwidth control method in multi-band OFDM transmission. Table I shows simulation conditions. The modulation scheme was 64QAM. The used band
numbers of multi-band and interfered systems were set to 3 and 1, respectively. The sub-carrier number of each band was 64, and the FFT point number was 4096. In this letter, the typical model of a transmission non-linear amplifier (NLA) was used [4], and its input back-off value was set to be 6 dB. The clipping level of clipping and filtering was set to be 3 dB, and iteration number was 5. The total power ratio of own thermal noise and interference from unknown external systems to received signals of the interfered system was set to be 15 dB.

| Table I. Simulation conditions. |
|--------------------------------|
| Modulation         | 64QAM             |
| Used Band Number   | 3                 |
| Sub-Carrier Number | $64 \times 3$    |
| FFT Point Number   | 4096              |
| Input Back-off of NLA | 6 dB              |
| Clipping Level     | 3 dB              |
| Iteration Number   | 5                 |
| Total Noise Ratio by Own and External System | $-15$ dB |

Figs. 2(a) and (b) show SINR performance of the interfered system on the adjacent band of the case 1 as shown in Fig. 1(a). In these figures, the received power ratio of the multi-band system to the interfered system, $P_i$, is set to be 20 dB and 30 dB, respectively. They clarify the SINR of the interfered system to band utilization rates of the multi-band system according to bandwidth control band selection where the control with all three bands, two adjacent bands of B1 and B2, and one of the adjacent bands is performed. The band utilization rate of three band control can be set to be 0 to 100 %, in which the use of 0 % is only the interfered system without the multi-band system. The SINR without the multi-band system becomes 14.3 dB because of distortion noise by the NLA used in the interfered system. The range of the rates by two-band and one-band control is 33.3 to 100 % and 66.7 to 100 %, respectively.

The results show that the band use of 100 % in the multi-band system significantly degrades the SINR of the interfered system with lower received power, and bandwidth control needs to satisfy required interference conditions for spectrum sharing. In bandwidth control, the control of all three bands is the most effective in interference reduction of the adjacent band. It achieves the SINR of 14 dB at the use of 50 % and $P_i$ of 30 dB which is nearly equal to the SINR without the multi-band system. On the other hand, the rate of two band control decreases to less than 40 % and one band control cannot achieve the SINR. This is because it can reduce distortion noise by narrowing adjacent bands and the noise caused by IM3 among three bands on the considered adjacent band.

Figs. 2(c) and (d) show SINR performance of the interfered system on the IM3 band of the case 2 as shown in Fig. 1(a). $P_i$ is set to be 20 dB and 30 dB. The control is with all three bands, two IM3 bands of B2 and B3, one of the IM3 bands. In the case of IM3 band use, the one band control is the most effective, and it can achieve the SINR of 14.3 dB at 66.7 %, while the rate of two band control becomes
40%. In the control of all three bands, the rate decreases to 30%. This is because distortion noise by IM3 is directly reduced by narrowing one of the bands causing IM3.

The above results confirm that the appropriate selection of bandwidth control bands according to the bands used by spectrum sharing systems can increase the effect of out-of-band noise reduction which can reduce inter-system interference in spectrum sharing.

**Fig. 2. Simulation results.**

### 4 Conclusion

This paper has proposed an adaptive bandwidth control method in a transmitter of a multi-band system with spectrum sharing to reduce inter-system interference. The evaluation results by computer simulation show that the proposed bandwidth control by adaptive band selection can reduce out-of-band distortion noise power so that the required interference power conditions can be satisfied in other spectrum sharing systems.

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