Inter-system interference reduction of adaptive bandwidth control for multi-band wireless transmission

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Abstract: This letter evaluates inter-system interference reduction effect by the adaptive bandwidth control method for a spectrum sharing multi-band system according to the bands used by an interfered system, the inter-system power ratio of spectrum sharing systems, and interference power from unknown external systems. The method adaptively selects bandwidth control bands among allocated multiple bands to effectively reduce out-of-band distortion noise which interferes to other spectrum sharing systems. The evaluation results clarify appropriate band selection for interfered system band position, and show the effective range of the method to inter-system power ratios and unknown external system interference.

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

Classification: Wireless Communication Technologies

References

[1] Y. Inuzuka, S. Tomisato, K. Uehara, S. Shimizu, and Y. Suzuki, “Adaptive bandwidth control for multi-band OFDM transmission with spectrum sharing,” IEICE Commun. Express, vol. 9, no. 5, pp. 131–135, May 2020. DOI: 10.1587/comex.2020XBL0003

[2] N. Takamatsu, S. Tomisato, K. Uehara, S. Shimizu, and Y. Suzuki, “A bandwidth control method by adaptive multi-band selection for spectrum sharing wireless communication system,” Proc. IEICE International Conference on Emerging Technologies for Communications (ICETC2020), Dec. 2020.

[3] S. Masaki, S. Tomisato, S. Denno, M. Hata, T. Furuno, and Y. Oda, “A non-linear distortion noise power control method for multi-band OFDM transmission,” Proc. WPMC 2014, pp. 440–443, Sept. 2014. DOI: 10.1109/WPMC.2014.7014915

[4] C. Rapp, “Effects of HPA-nonlinearity on a 4DPSK/OFDM signal for a digital sound broadcasting system,” Proc. Second European Conference on Satellite Communications, pp. 179–184, Oct. 1991.
1 Introduction
Spectrum sharing is one of promising technologies to increase wireless IoT (Internet-of-Things) network capacity, and multi-band signal transmission which simultaneously utilizes multiple frequency bands is an effective technology to realize flexible and efficient frequency band utilization. In such multi-band systems using Orthogonal Frequency Division Multiplexing (OFDM) transmission, the accumulation of out-of-band noise caused by the nonlinearity of a transmission power amplifier becomes harmful interference with other terminals when a lot of IoT terminals for various systems share the same frequency bands.

An adaptive bandwidth control method for multi-band systems was proposed to reduce this out-of-band noise, and its out-of-band noise reduction effect was evaluated [1, 2]. This method adaptively selects bandwidth control bands among allocated bands corresponding to the band position used by an interfered system to effectively reduce out-of-band noise on the used bands. In the method, peak power component detection followed by in-band and out-of-band filtering is used to reduce the noise [3].

This letter evaluates inter-system interference reduction effect by the proposed adaptive bandwidth control method according to the bands used by an interfered system, the inter-system power ratio of spectrum sharing systems, and interference power from unknown external systems.

2 System model and adaptive bandwidth control
Figure 1 shows the system model in which a multi-band wireless system with OFDM transmission and another system share the same frequency bands. The multi-band system simultaneously utilizes 5 bands of B1, B2, B3, B4 and B5. This simultaneous multi-band utilization causes serious out-of-band noise by inter-modulation distortion, and noise power on adjacent and third order inter-modulation distortion (IM3) bands becomes larger. Such out-of-band noise interferes to another spectrum sharing system. When the received out-of-band noise caused by the multi-band system on the interfered system band is extremely larger than own received signal power, the interference by the noise cannot be ignored. This shows that the inter-system power ratio of multi-band and interfered systems is an important factor in out-of-band noise interference evaluation. In addition, interference increases by the received signals from unknown external systems using the same frequency bands. In this letter, two cases, Case1 and Case2, are considered where an interfered system is assigned on the adjacent or IM3 band and is interfered by both out-of-band noise of a multi-band system and interference from unknown external systems as shown in Fig. 1(a).

Figure 1(b) illustrates an adaptive bandwidth control method which adaptively selects bandwidth control bands according to the band position of an interfered system and narrows the selected bands to reduce out-of-band noise in a multi-band system. Because the method yields unused bands in usable bands, it can generate out-of-band noise reduction signals on the unused bands by iterative peak power component detection and filtering [3].

Figure 1(c) shows an OFDM transmitter with an adaptive bandwidth control method. Transmitted signals are assigned to the frequency bands selected by the
method which selects the control bands according to the used band position and received power ratio of the interfered system, and OFDM signals in time domain are generated by IFFT processing. After the processing, peak power component detection followed by in-band and out-of-band filtering is performed to reduce out-of-band noise. Figure 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 in the usable band as shown in Fig. 1(e). The peak power detection and filtering are iteratively performed to accurately generate out-of-band noise reduction signals on unused bands. These generated out-of-band noise reduction signals are added to the narrowed multi-band OFDM signals, and out-of-band noise are reduced on the bands of the interfered system.
3 Evaluation results

Computer simulations were conducted to clarify the effect of the adaptive bandwidth control method in multi-band OFDM transmission according to inter-system power ratios and interference power from unknown external systems. Table I shows simulation conditions. The modulation scheme was 64QAM. The used band numbers of multi-band and interfered systems were set to 5 and 1, respectively. When the adaptive method is used in wireless LAN systems, 5 GHz frequency bands are used. 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 for peak power detection was set to be 3 dB, and iteration number of peak power detection and filtering was 5 for a multi-band system. The carrier signal power ratio of the interfered system to total noise power of own thermal noise and interference from unknown external systems, CNR, was set to be 10 dB and 25 dB.

| Table I. Simulation conditions. |
|-------------------------------|
| Modulation | Multi-band | Interfered System |
| Used band number | 5 | 1 |
| Sub-carrier Number | 64 × 5 | 64 |
| FFT point number | 4096 |
| Input back-off of NLA | 6 dB |
| Clipping level | 3 dB | – |
| Iteration number | 5 | – |
| CNR | – | 10 dB, 25dB |

Figures 2(a) and (b) show Signal-to-Interference and noise ratio (SINR) performance of the interfered system on the adjacent band of Case 1 as shown in Fig. 1(a). In these figures, the inter-system power ratio which is the received power ratio of the multi-band system to the interfered system, \( P_I \), is set to be 20 dB and 30 dB. The bandwidth control with 4 types of band selection methods is used where the Band 4 to 5 type preferentially narrows the bandwidth of Band 4 before Band 5 narrowing, the Band 5 to 4 type preferentially narrows the bandwidth of Band 5 before Band 4 narrowing, the Band 4 and 5 type equally narrows the bandwidth of Band 4 and 5, and the ALL type equally narrows the bandwidth of all usable bands.

The results show that the SINR of the interfered system can be improved by decreasing band utilization rates of the multi-band system, and the ALL type can achieve the highest SINR for the adjacent band of Case 1. This shows that equal bandwidth narrowing is appropriate for adjacent band distortion noise reduction. Figure 2(a) shows that the SINR difference by the band selection types becomes small at \( P_I \) of 20 dB and the CNR of 10 dB where unknown external system interference can be considered large enough and it is dominate in SINRs. On the other hand, the SINR difference in Fig. 2(b) becomes up to 2.5 dB at \( P_I \) of 30 dB and the CNR of 25 dB where both received power of an interfered system and unknown external system interference is in a low region, and out-of-band noise reduction is effective in SINR improvement.
Figures 2(c) and (d) show SINR performance of the interfered system on the IM3 band of Case 2 as shown in Fig. 1(a). $P_I$ is set to be 20 dB and 30 dB, and the same 4 types of band selection methods for bandwidth control are used.

The results have the same tendency as those of Case 1 to band utilization rates of the multi-band system. However, for the IM3 band, the results show that the Band 5 to 4 type is the most effective in SINR improvement because the type can directly reduce the signal power of Band 4 and 5 that cause IM3 in Case 2. Fig. 2(c) also shows that the SINR difference is small at $P_I$ of 20 dB and the CNR of 10 dB where the CNR is in a low region and unknown external system interference is dominate in SINRs. Figure 2(d) shows that the SINR difference becomes up to 6 dB at $P_I$ of 30 dB and the CNR of 25 dB where both the inter-system power ratio and the CNR is in a high region, and out-of-band noise reduction is dominate in SINR improvement.

The above results confirm the appropriate band selection of adaptive bandwidth control according to the band utilization of an interfered system and the effective range of the adaptive bandwidth control to reduce inter-system interference in inter-system power ratios and unknown external system interference.

### 4 Conclusion

This letter has evaluated inter-system interference reduction effect by adaptive bandwidth control according to the band utilization of an interfered system, the inter-system power ratios, and unknown external system interference. The evaluation
results confirm appropriate bandwidth control band selection for the band utilization of spectrum sharing systems and the effective range in inter-system power ratios and unknown external system interference.

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