Operational range increasement for STPA-BAA spectrum superposing using subcarrier modulation adaptation

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Abstract: In order to achieve high-speed and large-capacity communication, efficient use of frequency resources even over different wireless communication systems is an important issue. We previously proposed the spectrum superposing scheme using subcarrier transmission power assignment (STPA) and blind adaptive array (BAA). Even when multiple systems use the same frequency band, the secondary system enables the both receivers to mitigate inter-system interference by STPA-BAA. However, STPA-BAA has a problem that the operational region of the secondary system is limited due to low-level subcarriers. This paper attempts to resolve this issue by introducing subcarrier modulation adaptation. It can effectively expand the operational region of our proposed approach even in the low signal-to-noise-power-ratio (SNR) situation.

Keywords: blind adaptive array, subcarrier transmission power assignment, subcarrier adaptive modulation, spectrum superposing

Classification: Wireless Communication Technologies

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1 Introduction

Rapid spread of smartphones, tablets and wearable devices accelerate data traffic explosion. Since available frequency resources are exhausted, improving spectral efficiency is an essential issue. Spectrum sharing is in the process of becoming common sense emerged as licensed assisted access (LAA), long term evolution (LTE) in unlicensed spectrum (LTE-U) [1]. Addition to the above, we investigate a new concept as *spectrum superposing* in which multiple systems share spectral resource in spatial domain. It is assumed that the primary and secondary systems use the same frequency band without any interference from the secondary system to the primary system. The conceptual deployment scenario is shown in Fig. 1(a). This scheme is joint application of blind adaptive array (BAA) and subcarrier transmission power assignment (STPA) as shown in Fig. 1(b) [2, 3]. Interference signals are suppressed by BAA and the BAA is not required a priori information. However, BAA is limited to some operational throughput range at the situation that signal-to-interference-power-ratio (SIR) is nearly 0 dB. STPA changes the allocating power into high and low level deliberately for subcarriers. The STPA is also effective in reducing inter-system interference (ISI) to the primary system thanks to low-level subcarriers.

On the other hand, the applicability of this scheme is limited especially in low signal-to-noise-power-ratio (SNR) region. It is because the transmission power of

Fig. 1. system model.

the most low-level subcarriers is largely suppressed. Therefore, BAA weight optimization function is also limited. To overcome this issue, we extended our proposal by introducing a subcarrier modulation adaptation [4]. The transmitter provides QPSK to high-level subcarriers and BPSK to low-level ones. The modification is simple but it can improve throughput performance and operational SIR region compared to QPSK case in lower SNR situation [5]. This letter deepens the evaluation and discussion of our new approach in addition to [5] by examining various STPA parameters.

1.1 System model

The secondary system with STPA-BAA is laid over the primary one on the superposed spectrum under the situation of a multicarrier transmission system. Noted that there is no function of interference suppression in the primary system. On the same frequency resources, the secondary system basically must not give the interference to the primary system in the cognitive radio network. Therefore, interference from the primary transmitter must be suppressed by the secondary system concurrently with that the secondary system reduces interference to the primary receiver. SIR_k and SIR_{total} are denoted the SIR at the k -th ($1 \leq k \leq K$) subcarrier and the total SIR among all subcarriers, respectively. Their relationship is expressed as

$$SIR_k = \frac{S_k}{I_k}, \quad (1)$$

$$SIR_{total} = \sum_{k=1}^K \frac{S_k}{I_k}, \quad (2)$$

where S_k and I_k indicate the power of desired and interference signals at the k -th subcarrier, respectively.

2 Blind adaptive array with subcarrier transmission power assignment (STPA-BAA)

In the spectrum superposing scenario, we cannot obtain a priori information such as an interference signal or direction of arrival. The main feature of our proposal is to exploit two BAA schemes as constant module algorithm (CMA) and Eigenvector Beamspace Adaptive Array (EBAA) [2]; initial weight of CMA is provided by the 1st or 2nd eigenvectors. This combined scheme is defined as E-BSCMA which can enhance interference suppression performance of CMA. Originally CMA has a limitation in its operational region that the initial input SIR must be larger than 0 dB. E-BSCMA can alleviate its limitation, i.e. CMA initialized by the 2nd eigenvector can effectively work to suppress interference even at $SIR_k < 0$ dB.

Unfortunately, as stated above, input SIR_k cannot be available in the spectrum superposing scenario. As shown in Fig. 1(b), our original proposal deliberately assigned two levels of power density to each subcarriers: high-level or low-level at the transmitter. Receiver then assigns the 1st eigenvector-based E-BSCMA weight to high-level subcarriers and the 2nd one to low-level subcarriers. In the figure, G dB is the power difference of two levels subcarriers. F is the ratio of the number of

low-level subcarriers to high-level one. The power of total transmission is controlled so as to equal that of the conventional one. Exploiting such STPA strategy as a priori information, it enables the interference suppression when SIR_{total} is nearly 0 dB and its effectiveness was clarified through computer simulation [2] and experiment [3]. Remaining issue is that operational region provided by STPA-BAA reduces in lower SNR region; non-negligible bit error is caused due to low-level subcarriers.

3 Proposed scheme: Subcarrier modulation adaptation

Power density of low-level subcarriers at STPA-BAA should be suppressed to about 10 dB or more than the uniform power assignment so that the proposed scheme could be effective. Therefore, BER performance of low-level subcarriers is degraded due to their weak noise immunity as well as weight optimization failure, especially in lower SNR region. This issue affects overall performance of STPA-BAA and may limit its effectiveness in terms of SNR and operational SIR_{total} region where secondary system successfully obtain good throughput. The new proposed approach introduces subcarrier modulation adaptation where the transmitter provides QPSK to high-level subcarriers and BPSK to low-level ones. The conceptual illustration of this approach is shown in Fig. 1(b). Although BPSK has only a half information bit to QPSK, it exhibits a better BER performance than QPSK, and thus the throughput performance and operational region of STPA-BAA can be maintained even in lower SNR region. Applicability of higher order modulation should be further investigated, for example, applying a modified version of CMA known as multi modulus algorithm (MMA). It should be noted that the above modification can be implemented only to the secondary system. Interference reduction effect to the primary system can be guaranteed as it is.

4 Computer simulation

4.1 Simulation parameters

This letter assumes two pairs of transmitter and receiver communicates in a same frequency channel, respectively. Simulation parameters are listed in Table I. Spatially uncorrelated channels between a plurality of antennas are assumed. Our previously proposed STBA-BAA scheme is defined as the conventional.

4.2 Simulation results

Fig. 2(a) shows the operational region of the secondary system which is defined as the SIR_{total} range exceeding 4 Mbps throughput when SNR is 18 dB. Here we compare our new proposal with the conventional scheme in the various power difference of high and low levels subcarriers G . When G is lower than 14 dB, the operational range of the proposed scheme is narrower than the conventional one. Increasing G is effective in enlarging the operational SIR_{total} region of the proposed scheme with well covering around $SIR_{total} = 0$ dB. Larger G , over the 24 dB, cannot maintain the operational SIR region. As the result, we can conclude that the optimal G is from 16 dB to 20 dB and obtain the maximal 7.5 dB range at $G = 18$ dB. Fig. 2(b) shows throughput performance of secondary system versus SNR at

Table I. Simulation parameters

Parameters	Values
Number of Tx antenna, N_t	1
Number of Rx antenna, N_r	2
Modulation	BPSK, QPSK
FFT point	64
Number of data subcarriers, K	52
Number of data symbols, N_s	128
Number of pilot symbol	2
Guard Interval	16
Packets size	576 bytes
Channel model	IEEE 802.11 TGn Channel model D [6]
FFT windowing	ideal
Intra-system CSI estimation	Least square
Transmission bandwidth	20 MHz
Error correcting code	Convolutional Coding, $R = 1/2$
Subcarrier Tx power ratio, G	10, 12, 14, ..., 22 dB
Subcarrier number ratio, F	7

$SIR_{\text{total}} = 0$ dB and $G = 18$ dB. The proposed scheme shows the better throughput performance than the scheme with fixed QPSK at lower SNR region from 10 dB to 17.2 dB. This result verified that using BPSK at low-level subcarrier can improve the noise immunity under the environment of high-level noise. If modulation order is optimally chosen based on the measured SNR, throughput performance can be maximized in any SNR conditions.

5 Conclusion

This letter improved the operational region in STPA-BAA spectrum superposing scheme by introducing subcarrier modulation adaptation. As a modification, the secondary transmitter provides BPSK to low-level subcarriers in order to improve the noise immunity of the secondary receiver. Computer simulation verified its effectiveness in terms of throughput and operational SIR_{total} region especially at lower SNR situation. We can conclude the proposed approach is quite essential to stabilize advantages of our spectrum superposing approach. Our future work includes more sophisticated adaptive modulation and coding with respect to the reception SNR.

(a) Operational SIR_{total} region with G ($SNR = 18$ dB, $F = 7$).

(b) Throughput versus SNR ($SIR_{total} = 0$ dB, $G = 18$ dB, $F = 7$)

Fig. 2. Performances on the secondary system.

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