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Title	**Proposed E-MBS Channel Structure for 802.16m**	
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Re:	Call for Contribution on Project 802.16m System Description Document (SDD) issued on 2008-07-29 (IEEE 802.16m-08/003r4) Topic covered: PHY aspects of E-MBS	
Abstract	This contribution proposes to apply ‘group-wise scrambling’ for E-MBS channel structure. It allows FDM allocation between unicast and E-MBS channel and significantly improves MBS spectral efficiency.	
Purpose	For discussion and approval by TGm	
Notice		
Release		
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Proposed E-MBS Channel Structure for 802.16m

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1. Introduction

In IEEE 802.16m system requirement document (SRD) [1], it was agreed that the higher spectral efficiency is required in 16m E-MBS at a multi-cell multicast-broadcast single frequency networks (MBSFN) deployment. In this contribution, we propose to apply a 'group-wise scrambling' technique into 16m E-MBS channel structure to improve MBS spectral efficiency.

The group-wise scrambling consists of the following process.

First of all, MBS data sub-carriers are split into several sub-carrier groups. Each sub-carrier group is defined to include at least one pilot symbol. For each sub-carrier group, the phase rotation is employed to all MBS data. The phase is set the same as the BS-specific scrambling code which is used at the pilot symbol in the sub-carrier group.

There are two significant improvements in MBS spectral efficiency obtained from this technique.

First, since BS-specific pilot symbols are commonly used by both unicast and MBS data for channel estimation, FDM allocation of unicast and MBS resource becomes applicable without any additional pilot overhead. This makes it possible to apply the power boosting of MBS data transmission using a margin of the BS transmit power of unicast data transmission.

Second, the sub-carrier groups have the de-correlated channel response so that additional diversity gain is obtained.

We provide the detailed explanation about the group-wise scrambling technique and its effects in the following.

2. Proposed Group-wise Scrambling for E-MBS

2.1 Basic structure

First, we explain our proposed group-wise scrambling technique. [2]

In the following description, we define the structure where the BS-common pilot symbols are allocated as MBS-specific pilot as the conventional MBS structure.

Sub-carriers on which MBS data are transmitted are split into several sub-carrier groups as illustrated in Fig.1. Each sub-carrier group contains at least one pilot symbol, and each pilot symbol is scrambled with a BS-specific scrambling code. MBS data in each group are also scrambled with the same BS-specific code as the one used for the pilot. More precisely, pilot and MBS data in each group are rotated by the same amount as that of the BS-specific scrambling code. We refer to this process as 'group-wise scrambling'. Since the pilot and data in a group are multiplied by the same scrambling code, the received signal is equivalent to the pilot and data multiplied with the "combined" scrambling code of all surrounding BSs. Thus, the data can be equalized using the composite pilot, which is a sum of pilots including the effect of channel responses, without de-scrambling or separation of each BS-specific code. In other words, the scrambling process is transparent to the MS.

The detailed definition with mathematical expression is given in section 2.3.

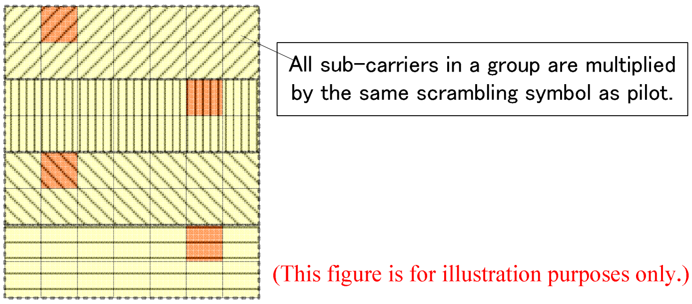

Fig.1. Basic structure of group-wise scrambling

2.2 Sub-carrier group partition

Regarding channel estimation of this structure, frequency domain interpolation or averaging cannot be applied across different sub-carrier groups, since the "combined" scrambling code is actually unknown at the MS. In order to enhance channel estimation capability, we define the sub-carrier groups as described in Fig.2.

In 802.16e specification [3], the BS-specific scrambling code is shifted by one sub-carrier per one symbol. Therefore, by splitting the sub-carrier groups diagonal, two pilot symbols within each sub-carrier group is multiplied by the same phase rotation by the BS-specific scrambling code. This means that the "combined" scrambling code is also the same between the pilot symbols. For example, as drawn in Fig.2, two pilot symbols in sub-carrier group #1 are multiplied by the same BS-specific scrambling code *d* (one of the complex values, 1+j, 1-j, -1+j or -1-j).

These pilot symbols in the same group can be averaged or interpolated to enhance channel estimation capability. This improves performance especially under large delay spread environments.

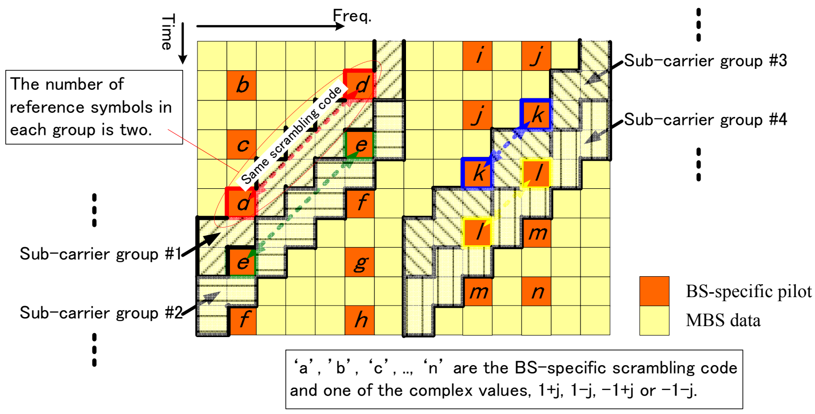

Fig.2 Sub-carrier group partition (PUSC allocation)

2.3 Additional Diversity Effect

By applying the group-wise scrambling, an additional diversity gain is introduced. In this section, we explain how it is done using a simple example of an MBS transmission employing 6 sub-carriers. A sub-carrier group is split as explained in section 2.2. Fig.3 and Fig.4 describe the cases of conventional MBS structure and proposed MBS structure with group-wise scrambling, respectively. For simplicity, we only consider two BSs and assume that the corresponding channels are stationary. In order to use the same notation in both cases, channel response vectors in the frequency domain are split into 3 sub-parts denoted h_{a1}, h_{a2}, h_{a3}, h_{b1}, h_{b2} and h_{b3}.

In the case of the conventional MBS structure, the same signals are transmitted from BS-A and BS-B as shown in Fig.3. Macro-diversity is achieved without any additional procedure at MS. In the case of proposed MBS structure with group-wise scrambling, the signals are the same at the beginning as well as the case of conventional MBS structure as described in Fig.4. The difference between the two cases is due to the group-wise scrambling process, framed in by a red dashed-line. In group-wise scrambling, sub-carriers are split into several sub-carrier groups and each sub-carrier group is rotated with BS-specific scrambling codes. In general, any scrambling code can be chosen for group-wise scrambling.

To understand how the group-scrambling introduces diversity gain, it is useful to compare the both composite channel response. The composite channel response of conventional MBS structure can be described as:

$$h_1 = h_{a1} + h_{b1}$$
$$h_2 = h_{a2} + h_{b2}$$
$$h_3 = h_{a3} + h_{b3} \quad (1)$$

The composite channel response of proposed MBS structure with group-wise scrambling can be described as:

$$h_1^{gs} = h_{a1}a_1 + h_{b1}b_1$$
$$h_2^{gs} = h_{a2}a_2 + h_{b2}b_2$$
$$h_3^{gs} = h_{a3}a_3 + h_{b3}b_3 \quad (2)$$

When a_i, a_j and b_i, b_j lie on the unit circle,

$$\mathrm{corr}\left(h_i^{gs}, h_j^{gs}\right) \le \mathrm{corr}\left(h_i, h_j\right), \quad (3)$$

since

$$\mathrm{corr}(h_i, h_j) = E[h_{ai} \cdot h_{aj}^*] + E[h_{bi} \cdot h_{bj}^*] + E[h_{ai} \cdot h_{bj}^*] + E[h_{bi} \cdot h_{aj}^*] \quad (4)$$

$$\mathrm{corr}(h_i^{gs}, h_j^{gs}) = a_i a_j^* \cdot E[h_{ai} \cdot h_{aj}^*] + b_i b_j^* \cdot E[h_{bi} \cdot h_{bj}^*] + a_i b_j^* \cdot E[h_{ai} \cdot h_{bj}^*] + a_j^* b_i \cdot E[h_{bi} \cdot h_{aj}^*] \quad (5)$$

(4) indicates that the correlation in (1) depends on delay spread and correlation of two BSs. On the other hand (5) indicates that the correlation in (2) depends on not only delay spread and correlation of two BSs but also on the correlations between scrambling codes a_i, a_j and b_i, b_j. If the scrambling codes are chosen randomly, the correlation can be decreased additionally.

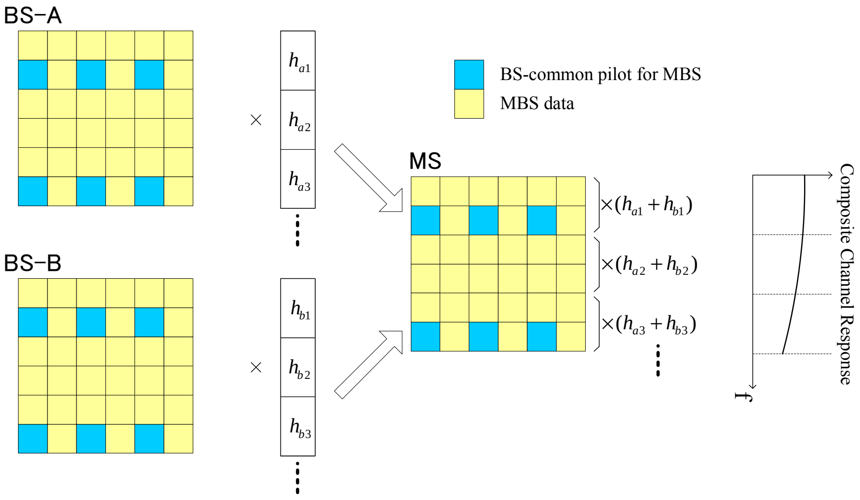

Fig.3 Conventional MBS structure

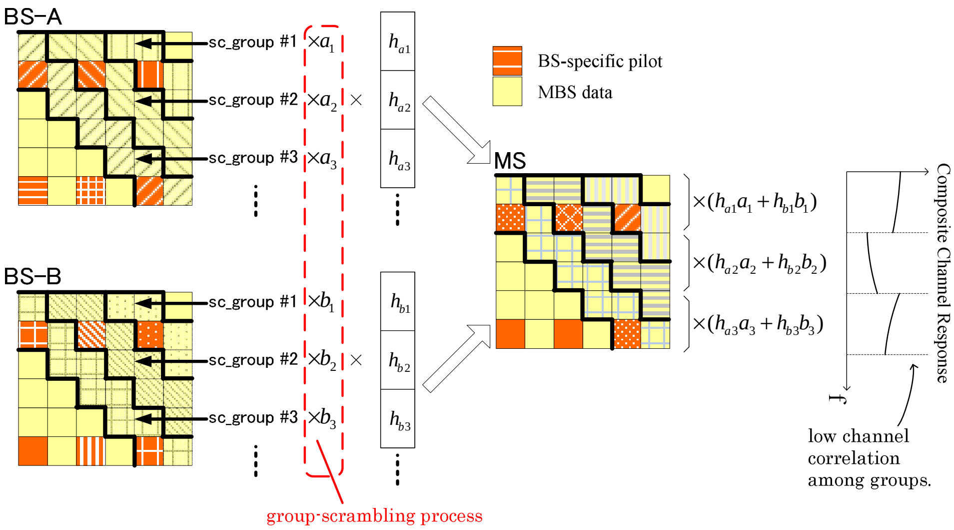

Fig.4 Proposed MBS structure with group-wise scrambling

3. Advantages

3.1 SubChannel based Cross-cast

In the conventional MBS structure, BS-common pilot symbols are necessary as MBS-specific pilot symbols to employ channel estimation of MBS data. It is certain that for subchannel based cross-cast allocation between unicast and MBS the pilot symbols of both unicast and MBS are necessary. This causes the significant pilot overhead increase. Here, 'cross-cast' means that flexible FDM allocation between unicast data and MBS data as illustrated in the right side of Fig.5.

On the other hand, applying the group-wise scrambling, unicast pilot symbols can be used as the MBS pilot symbols in common so that subchannel based cross-cast becomes possible.

In the Fig.5, the left and right side indicates the conventinal unicast/MBS resource allocation and subchannel based cross-cast with group-wise scrambling, respectively.

On the subchannel based cross-cast, it is not necessary to split the physical resource with the unicast region and the MBS region. Therefore MBS resource can be allocated piece by piece in distributed manner over long periods. This leads the significant effects, e.g. MBS boosting, time-diversity and enhanced flexibility of MBS resource allocation.

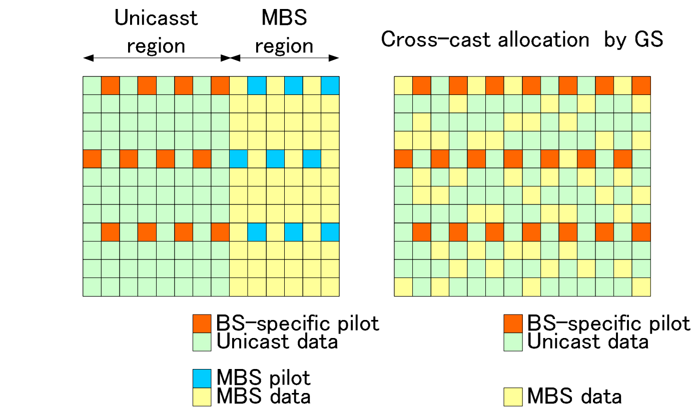

Fig.5. illustration of cross-cast with unicast and MBS

Now, we explain 'MBS boosting' referring to Fig.6.

In the unicast transmission case, with increasing the BS transmission power, the system throughput reaches a ceiling because of the inter-BSs interference. Especially, urban where BSs are closely-located in narrow region is typical deployment. In this case, even if the frequency resources are filled, a margin to the maximum BS transmission power remains.

On the other hand, MBS service is employed at a multi-cell multicast-broadcast single frequency networks (MBSFN) deployment. Consequently, BSs within the same MBS zone transmit the identical MBS data using the same time and frequency resource. Since MSs receive MBS signal with RF combining from such BSs, increase of BS transmission power leads improvement of MBS system throughput.

The purpose of MBS boosting is to allocate the margin of BS transmission power to MBS transmission. In the conventional structure illustrated the left side of Fig.6, since the symbols are separated for unicast and MBS by region, the margin at the unicast transmission cannot be used for MBS transmission.

On the other hand, in proposed MBS structure with group-wise scrambling the margin for unicast transmission power can be used for MBS transmission as illustrated right side of Fig.6. In this way, MBS boosting with group-wise scrambling leads the efficient use of BS transmission power resource and MBS system throughput improves without any unicast system throughput loss.

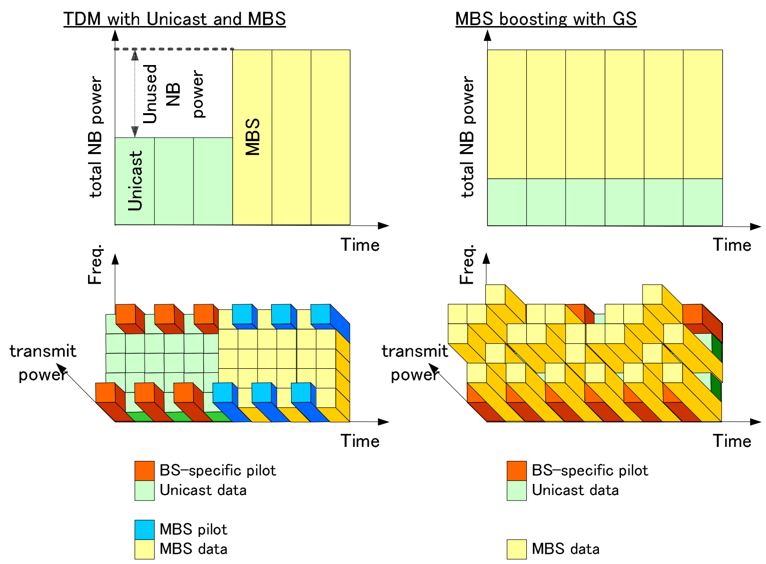

Fig.6. MBS boosting

3.2 Additional diversity gain

We discussed how E-MBS structure with group-wise scrambling provides transmit diversity at section 2.3. In the current section we present simulation results obtained with ideal channel estimation which show the transmit diversity gain due to group-wise scrambling. The simulation condition is summarized in Table 1.

We measured the channel model from the received signals assuming a 57-BSs configuration as shown in Fig.7. As a propagation model, we take into account only the distance-dependent path loss assuming a Pedestrian B channel model for all BSs. The inter-site distance (ISD) was set to 500m. We assumed that MS is located at the cell-boundary with a geometry value of 95%. At that location, the r.m.s delay spread becomes almost the worst condition from the viewpoint of the delay spread.

Fig.8 shows that the additional diversity gain due to group-wise scrambling, relative to conventional MBS structure, is approximately 1.1dB at 1% BLER. Note that group scrambling provides a gain in addition to a macro diversity gain in MBSFN system, which benefits both conventional and proposed MBS structure.

Table 1. Simulation condition

Inter-site distance	500m
System bandwidth	5MHz
Number of MBS symbols	6 OFDM symbol
Data modulation	16QAM
Channel coding	Turbo code (K=4, R=1/2) Max-Log-Map (8 iteration)
Channel estimation	Ideal
Path model	Pedestrian B
UE speed	3km/h(fD=5.55Hz)

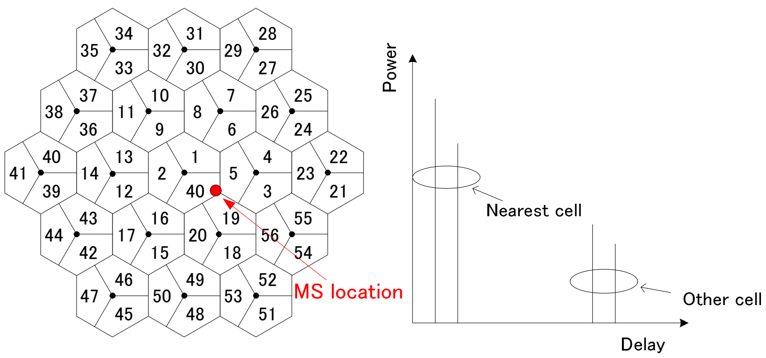

Fig.7. MS location

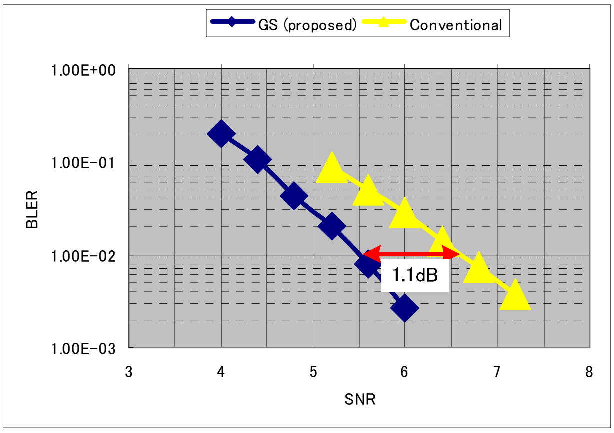

Fig.8. Simulation result (System BW: 5MHz)

4. Summary

In this contribution, we proposed to apply a group-wise scrambling technique into 16m E-MBS to improve MBS spectral efficiency. We showed two significant improvements in MBS spectral efficiency obtained from this technique. First, since BS-common pilot symbols are commonly used by both unicast and MBS data for channel estimation, FDM allocation between unicast and MBS resource becomes applicable without any additional pilot overhead. This makes it possible that power boosting of MBS data transmission using a margin of the BS transmit power of unicast data transmission. Second, the sub-carrier groups have the de-correlated channel response so that additional diversity gain is obtained.

Reference

[1] Mark Cudak, IEEE 802.16m-07/002r4, “IEEE 802.16m system requirements”
[2] Koji Akita, et al, "Group-Wise Scrambling Diversity for Broadcast and Multicast Services in OFDM Cellular System", VTC-2007 Fall. 2007 IEEE 66th, Sept.30 2007-Oct.3 2007 Page(s):174 – 178
[3] P802.16Rev2/D5, Part 16: Air Interface for Broadband Wireless Access Systems, June 2008
[4] Shknmbin Hamiti, IEEE 802.16m-08/003r4, “The Draft IEEE 802.16m System Description Document”
[5] Roshni Srinivasan, IEEE 802.16m-08/004r2, ”IEEE 802.16m Evaluation Methodology Document (EMD)”

Proposed Text

The following text is proposed to be captured in the IEEE 802.16m system description document (SDD).

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15. Support for Enhanced Multicast Broadcast Service

15.x E-MBS channel structure

To improve MBS spectral efficiency, a group-wise scrambling is to be considered. The group-wise scrambling implies pre-coding method for the MBS data. The process includes:

(1) All the MBS data sub-carriers are split into the sub-carrier groups with at least one pilot symbol.

(2) All the MBS data symbols in each sub-carrier group are rotated by the same amount of phase as that of pilot symbol. Consequently, the relative phase differences from the pilot symbol to the MBS data symbols become the same.

Since the signals within the sub-carrier group from each BS become the same, it is possible to realize the RF combining macro-diversity in the same manner as the BS-common pilot case.

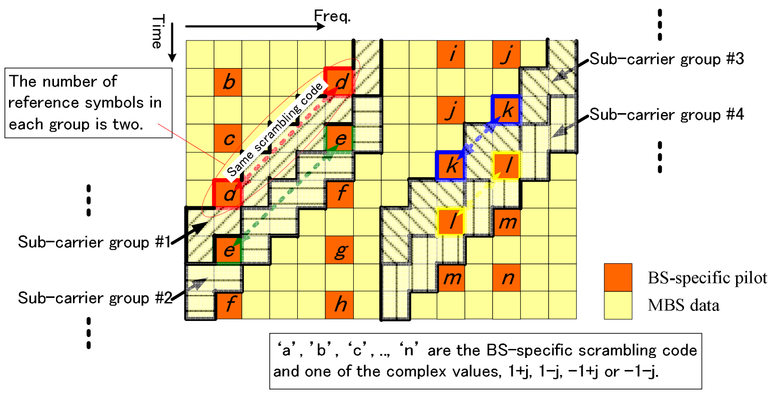

Fig. x. E-MBS channel structure with group-wise scrambling

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