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Title	**Sub-carrier Alignment for IEEE 802.16m Multi-band Frame Structure**
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Re:	Call for Comments on C802.16m-08/118r1 by TGm Frame Structure Rapporteur Group
Abstract	This contribution investigates the sub-carrier misalignment problem when multi-band frame structure is used in IEEE 802.16m. A simple method by adjusting RF center frequency and a supporting frequency offset estimation/reporting mechanism is provided for TGm discussion.
Purpose	Adopt the proposed text into TGm Frame Structure Rapporteur Group baseline document
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Sub-carrier Alignment for IEEE 802.16m Multi-band Frame Structure

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Abstract

In order to achieve the IMT-Advanced requirement on 1Gbps peak transmission rate, the legacy frame structure with 10MHz bandwidth is obviously not enough. The multi-band frame structure is expected to be a key to achieve Gbps transmission in IEEE 802.16m by using multiple RF carriers to utilize wider bandwidth. However, additional guard tones will be required if the sub-carriers in adjacent bands are not well aligned and hence degrade the spectrum efficiency. This contribution provides a simple method by adjusting RF center frequency along with a supporting frequency offset estimation/reporting mechanism to resolve this problem.

I. Sub-carrier Alignment Problem in IEEE 802.16m Multi-band Frame Structure

The multi-band (or called multi-carrier (RF carrier)) frame structure and operation have been presented in many contributions (C802.16m-07/282r2, 08/030, 08/031, 08/042r1 and etc.). A DL multi-band TDD frame structure is drawn as an example:

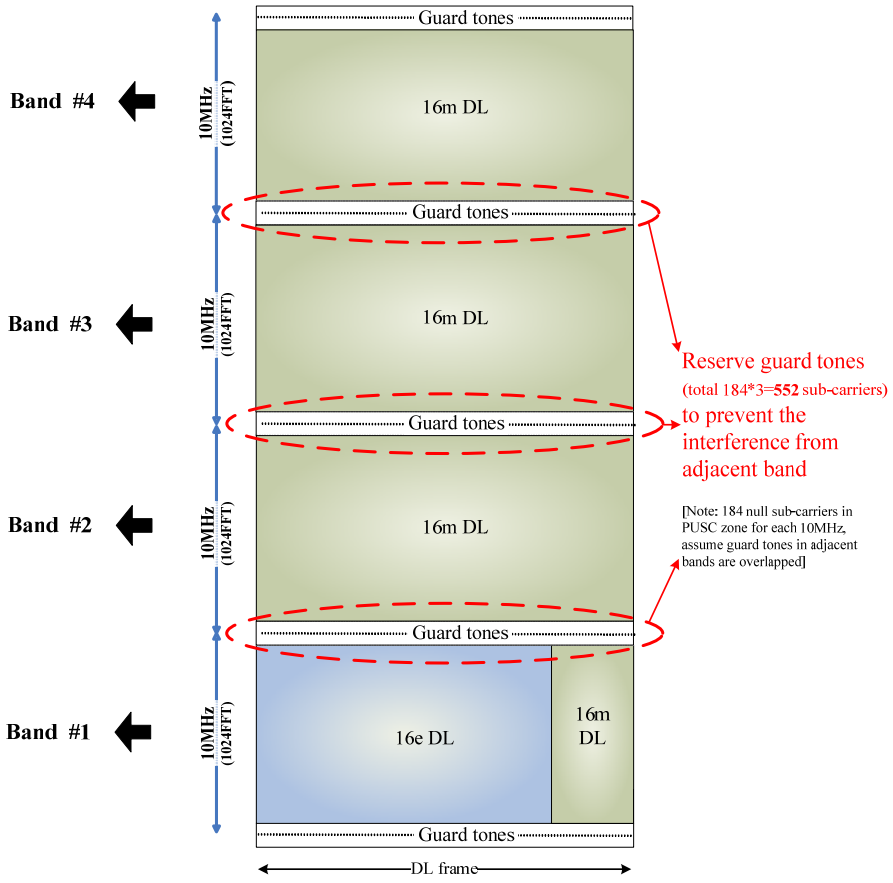
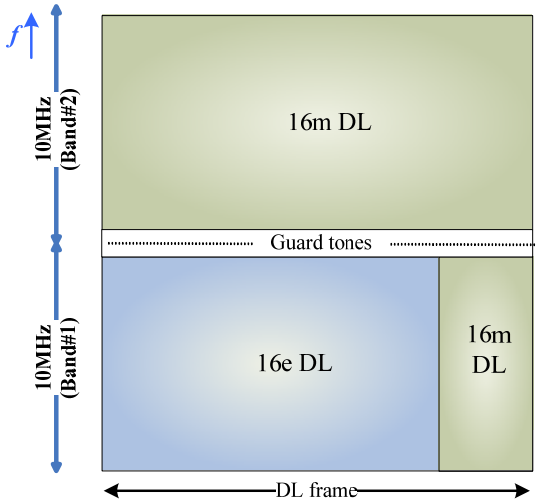
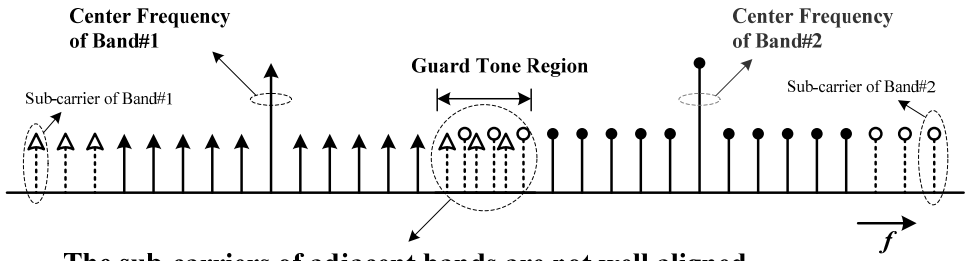


Figure 1 A DL multi-band frame structure example

In Figure 1, the OFDMA parameters for 16m zone/band are assumed to be the same as 16e zone/band. The guard tones between adjacent frequency bands are required to prevent the inter-carrier interference (ICI) due to the sub-carriers misalignment. Take the PUSC parameters as an example and assume the guard tones of adjacent bands are physically overlapped, Figure 1 shows that 552 sub-carriers are reserved for guard tones. Physically the frequency region where the guard tones are overlapped (i.e. guard tone regions) can be utilized to further improve spectrum efficiency, but there will be an ICI problem due to the subcarrier misalignment. For simple presentation, a frame structure example with only two bands is discussed as following.

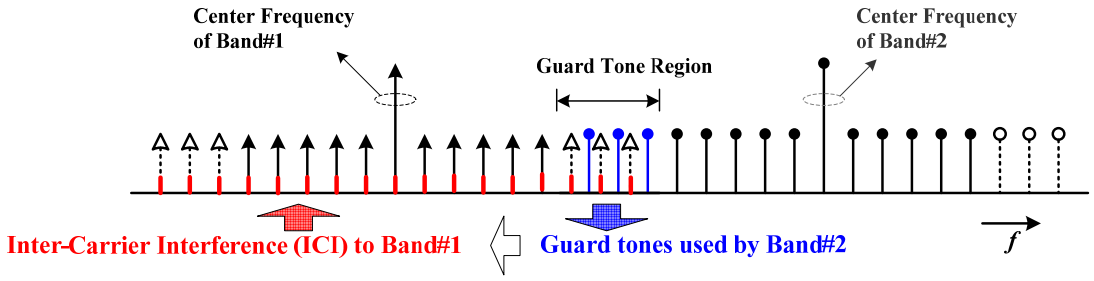


(a)



The sub-carriers of adjacent bands are not well aligned

(b)



The guard tones used by Band#2 are not orthogonal to the sub-carriers of Band#1

(c)

Figure 2. (a) A multi-band frame structure example with Band#1 and Band#2, (b) both Band#1 and Band#2 does not transmit data over the guard tone region; (c) the ICI incurred by sub-carriers

misalignment.

In Figure 2(b), the sub-carriers of Band#1 and Band#2 are not well aligned with each other (in frequency domain). This is resulted by the mismatch between fixed channel frequency step sizes (ex. 200kHz or 250kHz [1]) and 16e OFDMA parameter (i.e. 10.94kHz frequency spacing, Δf)[2] or the offset due to non-ideal RF frequency synthesizer. If Band#2 transmits data over the sub-carriers in guard tone region, as shown in Figure 2(c), the inter-carrier interference (ICI) will be incurred for the sub-carriers of Band#1. It is because those sub-carriers of Band#2 are not orthogonal to the sub-carriers of Band#1 (due to misalignment).

II. Resolution to Achieve Sub-carrier Alignment by Adjusting RF Center Frequency

Reserving those guard tones without data transmission can prevent this problem but will result in worse spectrum efficiency. A simple method to resolve this problem is adjusting RF center frequency to align those sub-carriers with each other.

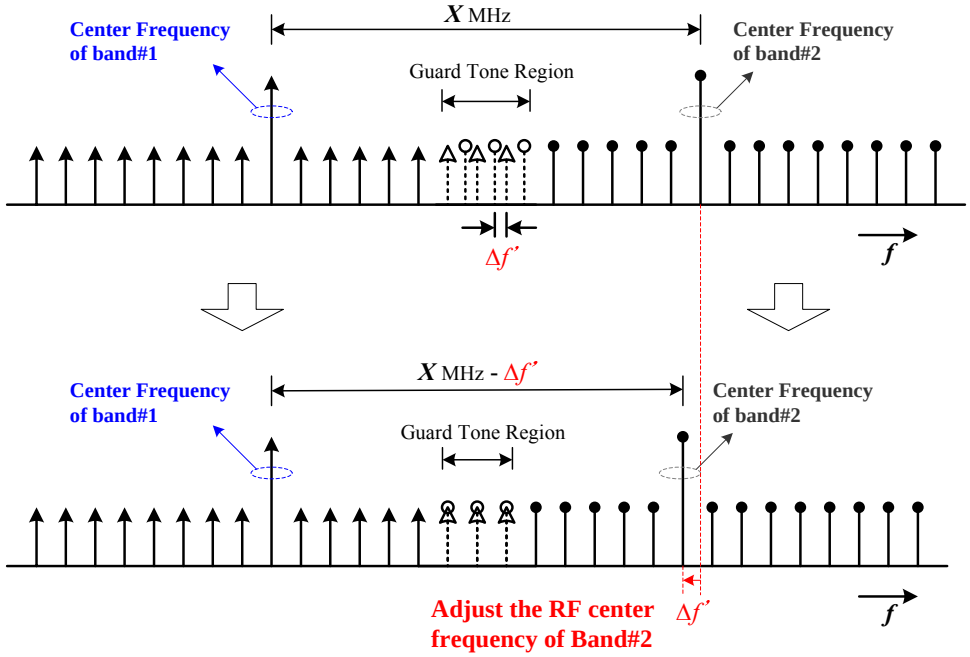


Figure 3. Adjust RF center frequency of Band#2 for sub-carrier alignment

The frequency offset ($\Delta f'$) between the sub-carriers of Band#1 and Band#2 is within the range:

$$-\Delta f/2 < \Delta f' \leq \Delta f/2$$

If the frequency spacing Δf is 10.94kHz, then the range of $\Delta f'$ will be

$$\mathbf{-5.47kHz} < \Delta f' \leq \mathbf{5.47kHz}$$

Note that the resolution of existing commercial RF synthesizer can work well for this.

III. A Frequency Offset Estimation/Reporting Mechanism to support Automatic Sub-carrier Alignment

In practical, there might be a problem to obtain $\Delta f'$ in advance of data transmission by Band#2. Here a mechanism is provided to resolve this problem.

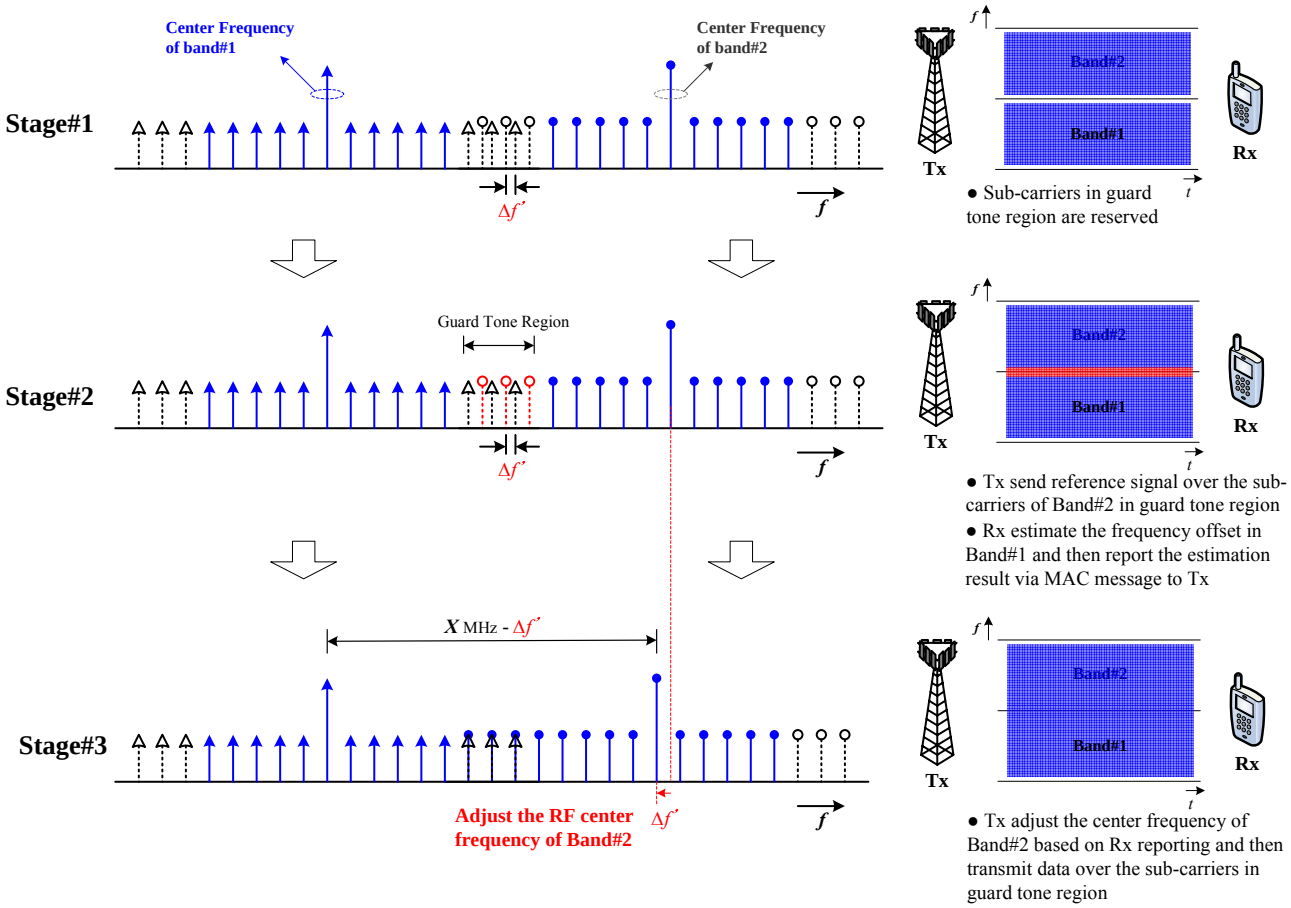


Figure 4. An example to perform frequency offset estimation for sub-carrier alignment

In Figure 4(a), the Tx transmits data to Rx in Band#1 and Band#2 without utilizing the sub-carriers in guard tone region. In Figure 4(b), the Tx sends a reference signal over the guard tone sub-carriers in Band#2. The reference signal here may be part of the preamble (if DL) or other reference signals (e.g. pilot). Then the Rx estimates the frequency offset ($\Delta f'$) of this reference signal via Band#1 and report this value through the MAC message in Band#1 or Band#2. In Figure 4(c), the Tx adjusts its RF center frequency of Band#2 based on the $\Delta f'$ report and then transmit data over the guard tone sub-carriers (either in Band#1 or Band#2).

IV. Summary

In this contribution, the sub-carrier misalignment problem of IEEE 802.16m multi-band frame structure is investigated. A simple method by adjusting RF center frequency can be used to resolve this problem, and a frequency offset estimation/reporting mechanism is also provided to support this method. By resolving the sub-carrier misalignment problem, the sub-carriers in guard tone regions can also be utilized for data transmission for higher spectrum efficiency.

V. Proposed Text Modification

----------Start of the Text----------

[*Add the following text after line#15, page#19 of C802.16m-08/118r1*]

11.4.6 Multicarrier Support in Frame Structure

11.4.6.1 Subcarrier Alignment for Adjacent Bands

When IEEE 802.16m multicarrier frame structure operates in single contiguous band with multiple RF carriers, part of the sub-carriers of adjacent frequency bands will be overlapped in a frequency region. In order to utilize these sub-carriers for data transmission, these sub-carriers shall be well aligned to prevent inter-carrier interference (ICI). The subcarrier alignment procedure is described as following:

1. The transmitter transmits a reference signal over the sub-carriers of Band#2 in the overlapped region
2. The receiver estimates the frequency offset ($\Delta f'$) of the reference signal on Band#1
3. The receiver reports the frequency offset via the MAC message to transmitter
4. The transmitter adjusts its RF center frequency based on the reported frequency offset to achieve sub-carrier alignment, which is shown as figure x.

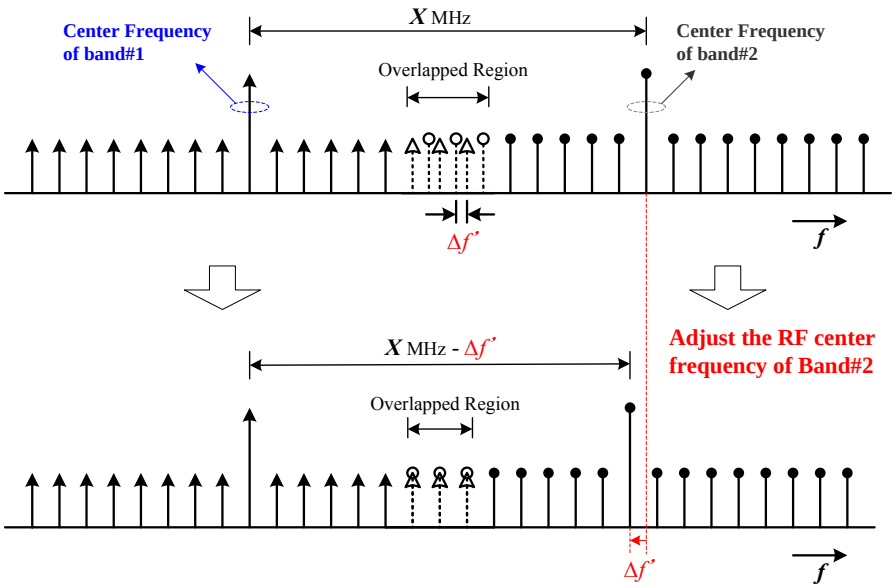


Figure x Sub-carrier alignment for multicarrier frame structure

----------End of the Text----------

References

[1] Hongyun Qu et al., “Proposal for IEEE 802.16m OFDMA numerology,” C802.16m-08/080r1, Jan. 2008.

[2] WiMAX Forum, “Mobile System Profile Release 1.0 Approved Specification,” Revision 1.4.0, Apr. 2007.