Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**OFDM preamble structure analysis and proposal.**
Date Submitted	**03/07/2001**
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Re:	OFDM preamble structure analysis and proposal.
Abstract	This document contains analysis and proposal for the OFDM preamble design for the 802.16ab system.
Purpose	This proposal should be used for the OFDM preamble design
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Patent Policy and Procedures	

Table of Contents

OFDM Preamble Structure

1 General

The preamble preceding an OFDM symbol is used for three major reasons:

- Frequency lock
- Start OFDM symbol identification
- Channel estimation

In an FWA system several assumptions could be made to help the preamble design.

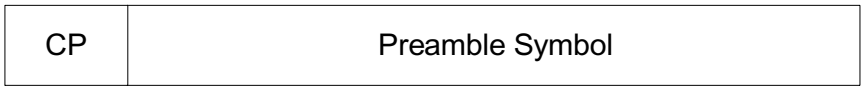
2 Down Link

Worst case we should look on is the TDD mode, due to the fact that the downlink bursts are disrupted. We can deduct several assumptions:

1. Users joining the system could take several frame durations to lock onto the system; there is no need for a user to sync on the first downlink burst he receives.
2. Due to slow changing channels (Doppler of 2-4Hz), timing frequency and channel estimation procedures could enjoy information from previous frames (longest frame today is 5ms).

From the above stated we could design the system to have only one preamble, without any short repetitions of preambles. Large frequency shift could be identified in the frequency domain rather than the time domain, and OFDM starting point could be assisted with formal information.

The next figure shows the preamble needed:



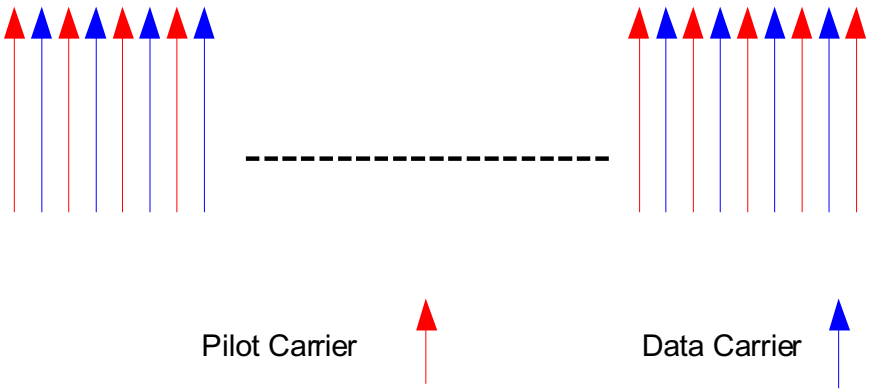
Further more:
The maximum Cyclic-Prefix (CP/GI) allowed is of _ length in respect to the symbol duration, therefore multipath exceeding this period of time could not be compensated and ISI will occur. If the ISI is larger than 10% of the symbol duration (multipath larger than 35% of the symbol duration), the symbol suffers from a very high level of ISI and needs long time equalizers (a thing we as OFDM people want to avoid).

Therefore we can now analyze the amount of pilots that are needed within the OFDM symbol in order to estimate echoes that are up to 35% of the symbol duration. The number of rotation created due to the longest echo will be:

$$N_{FFT} * 0.35$$

Were N_{FFT} is the number of carriers in the FFT.

When sampling the OFDM symbol in the middle of the echoes (getting the maximum estimation), and taking the Nyquist rule of two samples per the fastest rotation created, we need at least 1 pilot every $1/0.35 \cup 2.85$ carriers. In order to be on the save side (and consider also in some FFT modes the 7/6 clock factor) we could allow 1 pilot for every 2 carriers, the next figure shows the needed preamble:



This preamble structure will enable the channel estimation needed; the frequency shift detection (in the time and frequency domain), and one can base the OFDM symbol mechanisms on acquired knowledge on the current preamble and known knowledge from previous frames.

The data carriers within the preamble symbol are used for transmission of Data, with a burst size of half the amount of data in one OFDM symbol. Therefore gaining another half a symbol for every transmission.

3 Up Link

In the uplink some assumptions are not correct, and FDD/TDD modes are of the same nature.

1. Users have to be estimated per burst
2. We assume that users are time and frequency locked.
3. No prior information could be assumed (no guaranty that users shall transmit within short time intervals).
4. Same capability of multipath handling is to bee concerned with.

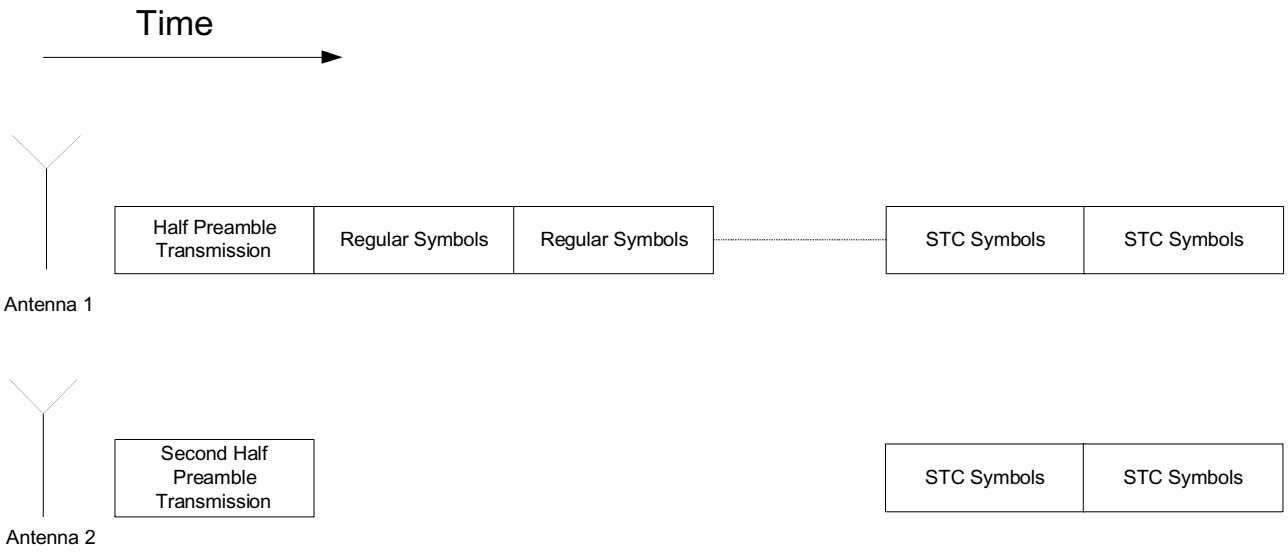
From the above stated we could design the system to have only one preamble, without any short repetitions of preambles.
The next figure shows the preamble needed:

The structure of the preamble symbol is the same as for the down link symbol, were half the carriers are used as pilots and half as data carriers.
The data carriers within the preamble symbol are used for transmission of Data, with a burst size of half the amount of data in one OFDM symbol.

This will enable a huge increase of throughput when considering a bursty uplink transmission, with short data payload (the same assumption is also true for high data throughput and high order modulation, in fact we will not waste all the channel bandwidth on users working only QPSK).

4 Space –Time Coding (STC) Usage and interoperability

In the space-time mode, the preamble could be used for both antenna transmissions in the same time, by using half of it for one antenna and the other half for the other antenna.
Interoperability within one stream of symbols for both STC users and regular users could be achieved by sending the preamble first from both antennas (regular users and STC users shall use only half for regular channel estimation), and regular symbols for all users (STC users can also receive regular transmission), and then STC symbols (were only users supporting STC could work).
A diagram representing the transmission scenario is shown below:



By using this scheme and the preamble structure interoperability within regular and STC transmission could be achieved seamlessly.

5 Conclusion

1. Analysis of the needed preamble length has been performed. The design proposed is very efficient and yet satisfies the OFDM needs.

2. The system will need only one preamble, which will increase its throughput in both uplink and downlink, and will give an elegant solution. The increase in the uplink is more dramatic than the downlink and could improve the system throughput by 5%-25%.
3. Moreover the preamble structure shall enable seamless interoperability between STC transmission and regular transmission (which is a great advantage for the OFDM system).
4. This solution could be used for any configuration of the system (Centralized, STC, Mesh etc.) by utilizing it s added value features and if needed using recording mechanism to enable better sync on the preamble.
5. The differences between the system using the modified preamble are estimated to be: 0-2dB, depending on the packet lengths.
6. Synchronization mechanisms could be used with any preamble structure taking into account the assumptions of the FBWA system (detailed in this document and the previous one).
7. We recommend that this preamble structure shall be used as the preamble in the 802.16ab system.

6 References

[1] H. Sari, Y. Levy, and G. Karam, "Orthogonal Frequency-Division Multiple Access for the Return Channel on CATV Networks," ICT ’96 Conf. Rec., vol. 1, pp. 52-57, April 1996, Istanbul, Turkey.

[2] H. Sari and G. Karam, "Orthogonal Frequency-Division Multiple Access and its Application to CATV Networks," European Transactions on Telecommunications (ETT), vol. 9, no. 6, pp. 507-516, November - December 1998.

[3] Richard V. Nee and Ramjee Prasad, OFDM for wireless multimedia communicatons , Artech House Publishers,2000.

[4] 802163c-00_33 – Initial OFDM/OFDMA PHY proposal for the 802.16.3 BWA

[5] 802163c-00_34 — Initial OFDMA/OFDMA PHY proposal for the 802.16.3 BWA

[6] 80216ab-01_01.zip — Combined 802.16.ab document

[7] 802.16.3c-01/29r1 — Channel model for fixed wireless applications