Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Relay Amble Modulation Series
Date Submitted	2007-03-05
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Re:	IEEE 802.16j-07/007r2
Abstract	This contribution provides a simple relay amble sequence set for the purpose of synchronization, channel estimation, carrier frequency estimation, etc. in the relay zone in mobile relay OFDMA systems. The proposed amble set satisfies the requirements of the relay zone ambles and solves the problems suffered by using the original preambles in the relay zone.
Purpose	For discussion and approval of inclusion of the proposed text into the P802.16j baseline document.
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Patent Policy and Procedures	

Relay Amble Modulation Series

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1. Introduction

In IEEE 802.16e systems, the first symbol of the downlink transmission is the preamble, which can be used by a mobile station (MS) to obtain the time synchronization, carrier frequency estimation, channel response estimation, cell and sector identification, and so on. A similar amble can also be introduced into the relay zones for relay stations (RSs) to achieve the similar objectives as the preambles, since RSs will no long receive the preamble in the access zone from the serving multi-hop relay base station (MR-BS) or parent RS after initial entry procedure when single-radio RS architecture is used.

A set of 114 preamble modulation series are specified in IEEE 802.16e. The following choices are available for this new amble sequence.

- One option of the relay zone amble is to use the same preamble sequence specified for 802.16e, i.e. the one used in the access zone in each sector/cell. The differentiation between the “legacy” amble and the relay amble should take place based on the FCH and MAPs following the preamble . However, this solution will cause problems since MSs could detect the same preamble twice in one frame, extending all the related network entry procedures.
- Another option is to use an amble structure, re-using the same PN sequence but allocating to the new relay amble sequence a different (lower) amplitude. However, in the high mobility environment it could be expected that fast-fading could cause significant variation in pathloss across the subframe that differentiation through amplitude will not be reliable.
- A third possibility is to split the pool of 114 PN sequences into two smaller PN sub-pools: one allocated for BSs and another one re-allocated for RSs. This solution has the dis-advantage of a relative small pool of RS sequences

In this contribution, we define a new solution which provides an amble sequence that avoids the drawbacks related to the other solutions outlined above.

We provide a new amble set with the following characteristics:

- The new PN sequence has an ideal PAPR (peak-to-average-power-ratio) performance, in otherwords the same as the current access preamble set.
- This amble set has a direct relationship with the preamble set used in a sector/cell.
- It has the same cross-correlation performance as the original preamble set. The cross-correlation between the proposed amble set and the original preamble set is good enough for the purpose of the amble series in relay zones.
- The new PN sequence requires minimal PHY development changes referenced to the “legacy” 16e PN sequence.

2. Requirements for the Amble Set in Relay Zones

The amble set in the relay zones is mainly used for the purpose of synchronization, carrier frequency tracking, and sector and cell identification. In order to achieve those objectives, an amble set shall have following properties:

1) A relay amble using the same amplitude like the original preamble and the same PAPR performance like the original preamble structure set is required, so that no extra power back-off is required for the MR-BS or RS transmitters
2) The same level of cross-correlation performance as the original preamble set is required, so that the objective of the amble set in the relay zone is fully satisfied
3) The cross-correlation between the amble set in relay zone and the original preamble set shall be low, so that the possibility of false preamble detection at the MSs caused by relay zone ambles is negligible (i.e. the MS should just ignore the RS amble set as it will not be correlated with any of the access preamble sets known to it)

3. Relay Amble Modulation Series

The new amble modulation series $PN_i^A, i = 0,1,...,113$ is related to the original preamble modulation series $PN_i, i = 0,1,...,113$ (specified in 8.4.6.1.1 in IEEE 802.16-2005) in the following way

$$PN_i^A(j) = PN_i(J - j), \quad i = 0,1,...,113, \; j = 0,1,...,J \qquad (1)$$

where J is dependent on the FFT size used in the system, which is equal to 567, 283,143 and 35 for an FFT size of 2048, 1024, 512 and 128, respectively. The new amble set is termed *Associated Amble* (*A-Amble*) *Modulation Series* in this document.

3.1 PAPR

The PAPR performance of the A-Amble series is depicted in Figs. 1a-1c for FFT Size of 2048, 1024 and 512 respectively.

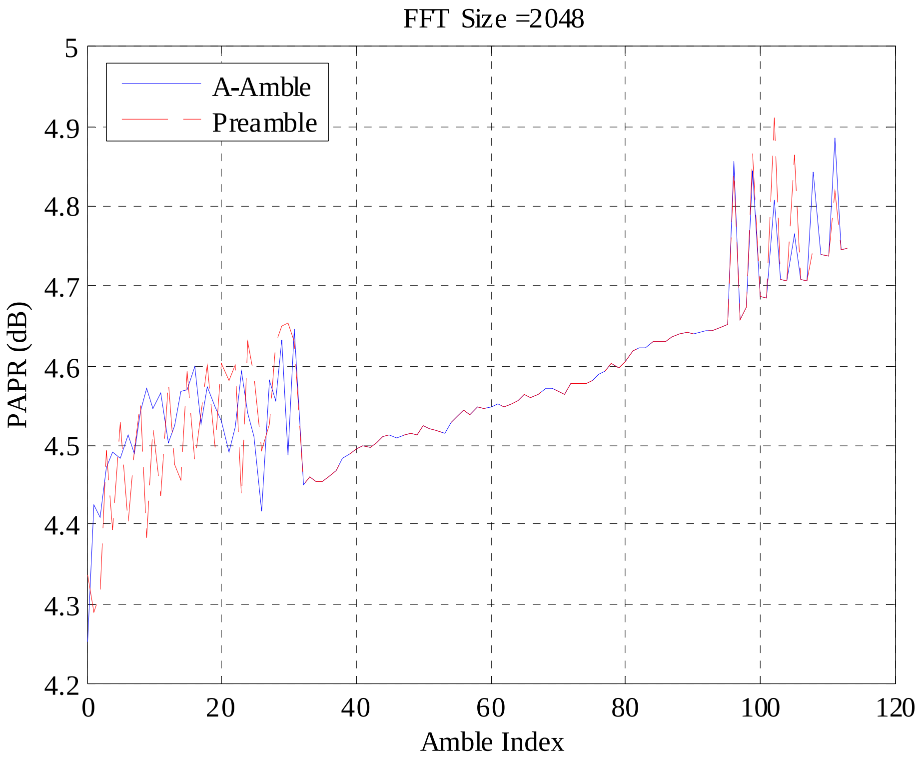

Fig. 1a PAPR performance for A-Amble series (FFT size = 2048)

It appears that the PAPR performance for A-Amble set is slightly better than that of the original preamble series for FFT size of 2048 and 1024. The PAPR performance for A-Amble set is equivalent to that for the preamble series when FFT size is 512. The maximum and mean value PAPR (of all 114 ambles) for A-Amble series is compared with those for the preamble series in Table 1.

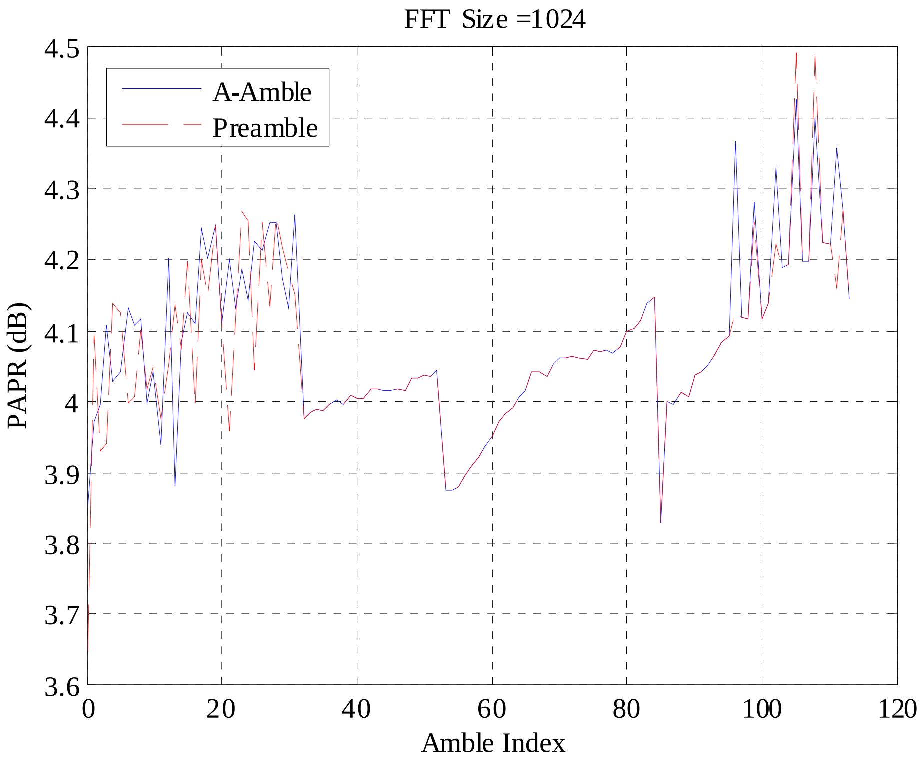

Fig. 1b PAPR performance for A-Amble series (FFT size = 1024)

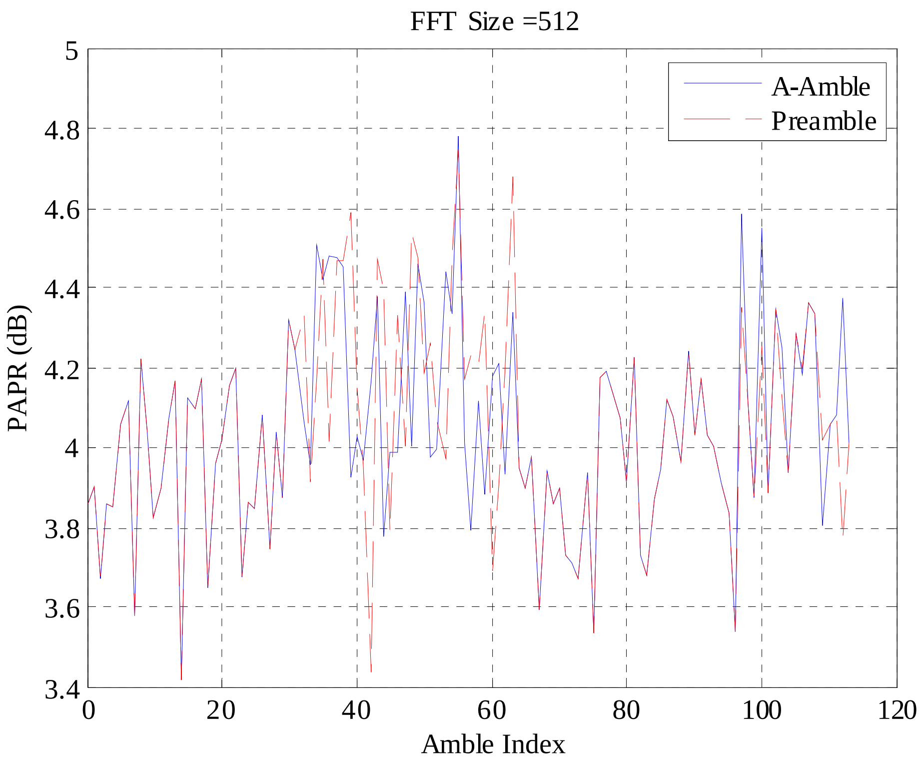

Fig. 1c PAPR performance for A-Amble series (FFT size = 512)

Table 1. Comparison of the maximum and mean value of PAPR

Ambles	Maximum PAPR			Mean PAPR		
	2048	1024	512	2048	1024	512
Preamble	4.91	4.49	4.75	4.58	4.07	4.05
A-Amble	4.89	4.44	4.78	4.58	4.08	4.04

3.2 Cross-Correlation Performance of A-Amble Series

It is easy to verify that A-Amble series has exactly the same cross-correlation performance as that for the original preamble series, since A-Amble series is the reverse version of the corresponding preamble series.

3.3 Cross-Correlation between A-Amble and Preamble Series

The normalized cross-correlation (by the auto-correlation) between A-Amble and the Preamble series is illustrated in Fig. 2a – 2c for FFT size of 2048, 1024 and 512, respectively.

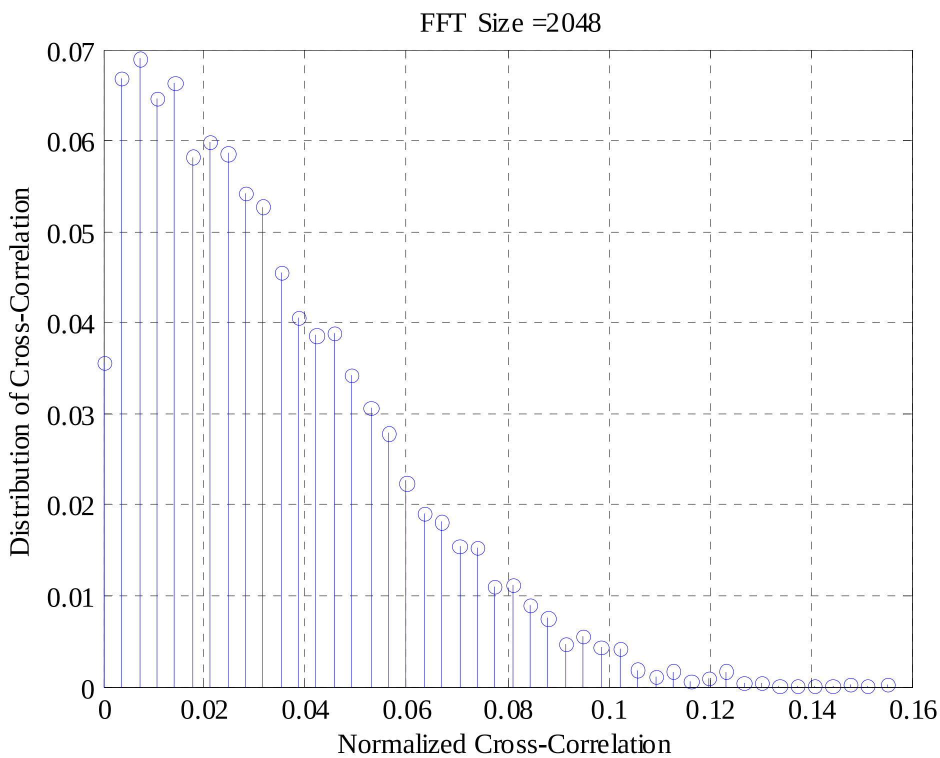

Fig. 2a Distribution of the cross-correlation between A-Amble and preamble series (FFT size = 2048)

The maximum of the cross-correlation between A-Amble series and preamble series for FFT size of 2048 is 0.154, which is less than 0.166, the maximum cross-correlation among preambles.

For FFT size of 1024, the maximum of the cross-correlation between A-Amble series and preamble series is 0.232 (maximum cross-correlation among preambles is 0.162), which is still good enough. Note that the maximum cross-correlation among preambles is 0.236 for FFT size of 512.

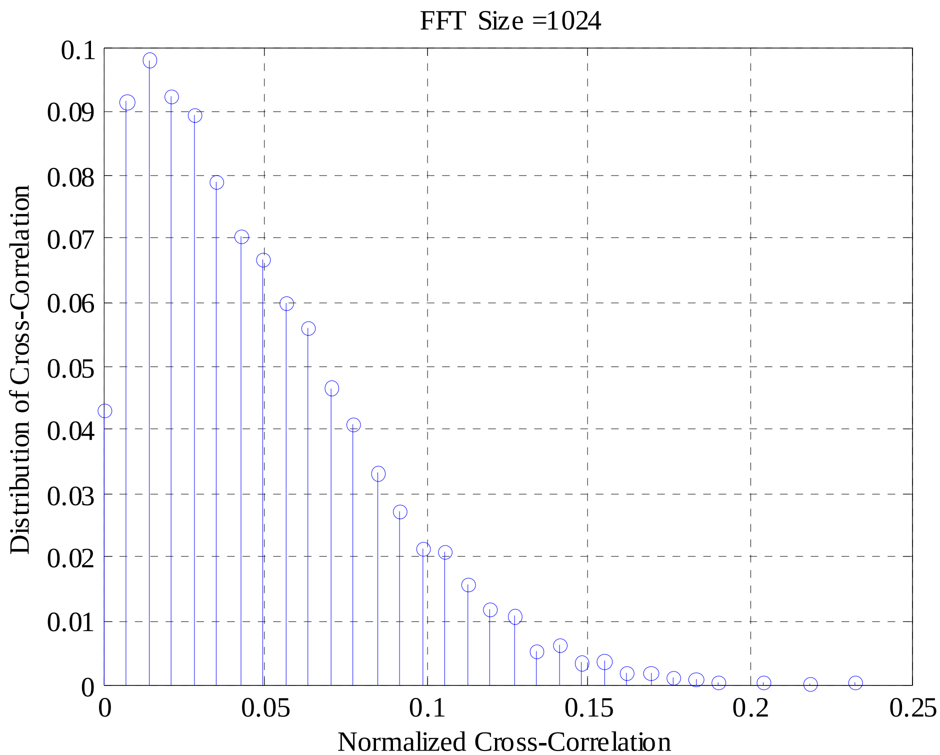

Fig. 2b Distribution of the cross-correlation between A-Amble and preamble series (FFT size = 1024)

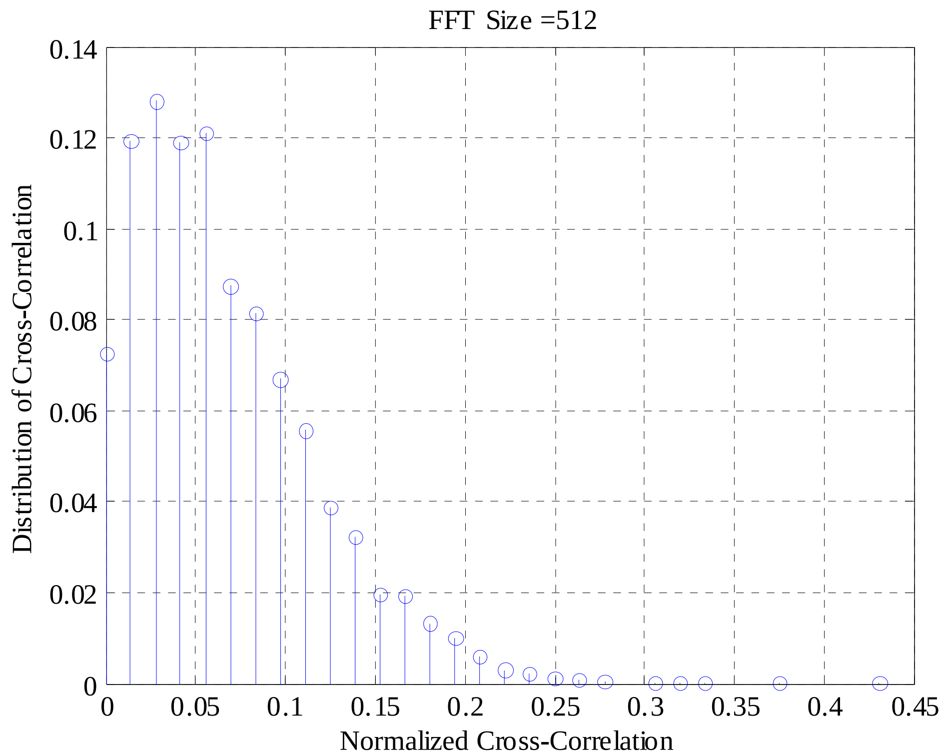

Fig. 2c Distribution of the cross-correlation between A-Amble and preamble series (FFT size = 512)

For FFT size of 512, the maximum cross-correlation between the two amble sets degrades to 0.43, which is still acceptable. Note that the maximum cross-correlation among preambles is 0.444 for FFT size of 128. Even for a cross-correlation of 0.43, it still provides 7.3 dB discrimination [$20\times log_{10}(1/0.43)$] between the interfering amble pairs. Furthermore, the probability for cross-correlation greater than 0.32 (corresponding to 10 dB discrimination) is only 6.12×10^{-4}, which is negligible.

The maximum cross-correlation among the two amble sets is summarized in Table 2. Although not presented here, the A-Amble set for a FFT size of 128 is also acceptable. The A-Amble set has better PAPR performance than the preamble set. However, the maximum cross-correlation between two amble sets degrades to 0.72, which corresponds to 3dB discriminations. Another 3 dB or more power back-off for the A-Amble set is recommended when it is used for a FFT size of 128.

Table 2. Maximum cross-correlation between A-Amble and preamble series

FFT Size	2048	1024	512
Cross-Correlation of Preambles	0.166	0.162	0.24
Cross-Correlation between amble sets	0.154	0.232	0.43

4. Conclusions

A new amble set, called the associated amble, is proposed to be used as the relay amble in the relay zone for the purpose of synchronization, carrier frequency tracking and so on. The new amble series has following properties,

1) There is one and only one associated amble for each preamble defined in IEEE 802.16-2005; hence no extra efforts are required for the new amble planning in the network deployment. Therefore the relay amble set index is the same as the access preamble index used at any one amble transmitting station.
2) The relay amble modulation series has the same auto-correlation and cross-correlation performance as the original preamble modulation series. This property makes the relay amble set work as well as the original preamble set
3) Each relay amble series has the same or better PAPR performance than the corresponding preamble series
4) The cross-correlation between the relay amble modulation series and the original preamble modulation series is low enough for the purpose of the amble series in relay zones
5) The relay amble series has a simple relationship with the corresponding preamble series and is easy to be implemented

5. Specific text changes

Insert new subclause 8.4.6.1.1.3:

8.4.6.1.1.3 Relay amble

The relay amble series $PN_i^A, i = 0, 1, ..., 113, \ j = 0, 1, ..., J$ shall be obtained by reverse the corresponding preamble series in 8.4.6.1.1, i.e.

$$PN_i^A(j) = PN_i(J - j), \quad i = 0, 1, ..., 113, \ j = 0, 1, ..., J$$

where PN_i is the preamble series with index of i, and J is 567, 283,143 and 35 for an FFT size of 2048, 1024, 512 and 128, respectively. The index of the relay amble series used shall be the same as that of the preamble series used in the access zone of the sector or cell.

The relay amble series shall be modulated using boosted BPSK modulation, as specified in 8.4.9.4.3.3.