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Re:	IEEE 802.16j-06/027: “Call for Technical Proposals regarding IEEE Project P802.16j”
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.
Notice	
Release	

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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.

- The first 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 different (lower) amplitude. However, in the high mobility environment it could be expected that fast-fading could cause significant variation in path loss 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 disadvantage of a relative small pool of RS sequences

In this contribution, we define a new solution which aims to fix the amble related PN sequence, avoiding 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 other words the same as the current access preamble set, for FFT size of 2k, 1k and 512.
- The amble set has a direct relationship with the access preamble 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.
- The PAPR performance of the proposed amble set for FFT size of 128 is about 1dB worse than the original preamble set

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 desired, so that no extra power backoff 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

3.1 Relay Amble Series for FFT Size of 2k and 1k

The new amble modulation series $PN_i^A, i = 0,1,...,113$ for FFT size of 2k and 1k 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 the PN sequence length, which is equal to 567 and 283 for FFT size of 2048 and 1024, respectively. This new amble set is termed *Associated Amble* (*A-Amble*) *Modulation Series* in this document.

3.2 Relay Amble Series for FFT Size of 512 and 128

The new amble modulation series $PN_i^R, i = 0,1,...,113$ for FFT size of 512 and 128 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

$$PN_i^R(j) = \begin{cases} PN_i(j + s), & j = 0,1,...,J - s \\ PN_i(j + s - J - 1), & j = J - s + 1,...,J \end{cases} \quad i = 0,1,...,113 \qquad (2)$$

where J is 143 and 35 for FFT size of 512 and 128, respectively, and s is 2 and 1 for FFT size of 512 and 128, respectively.

4. Performance of the Relay Amble Modulation Series

4.1 PAPR

The PAPR performance of the relay amble series is depicted in Figs. 1a-1d for FFT Size of 2048, 1024, 512 and 128, respectively.

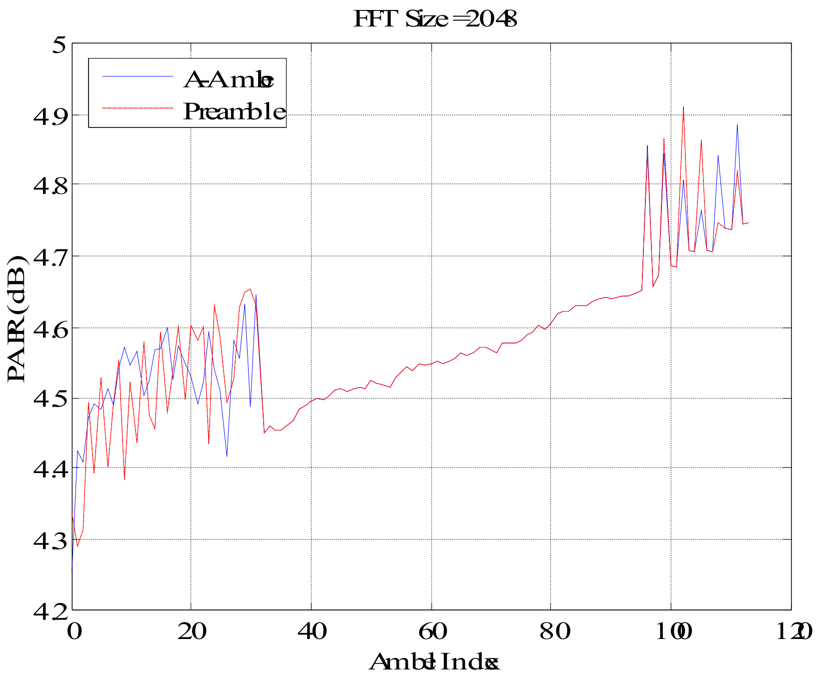

Fig. 1a PAPR performance for relay amble series (FFT size = 2048)

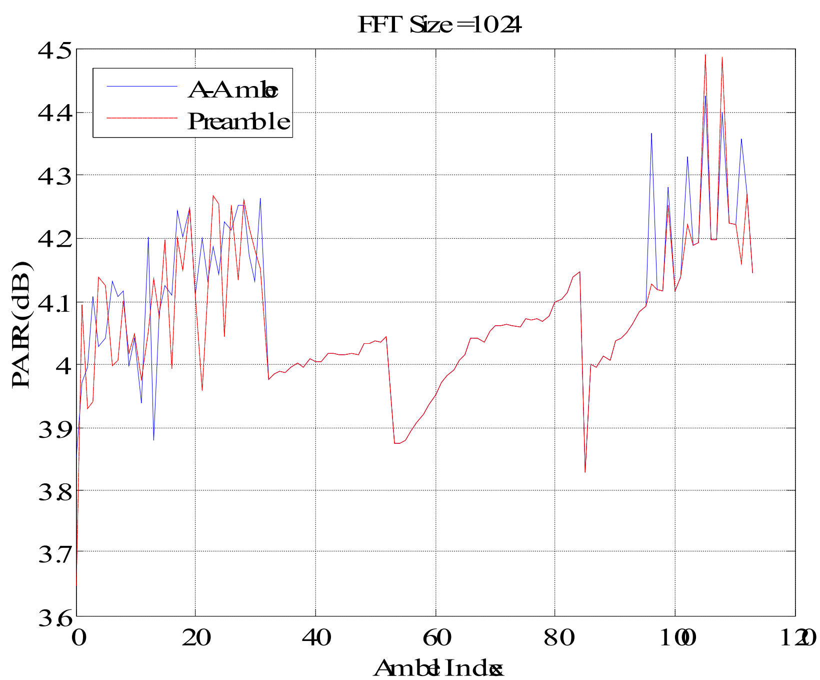

Fig. 1b PAPR performance for relay amble series (FFT size = 1024)

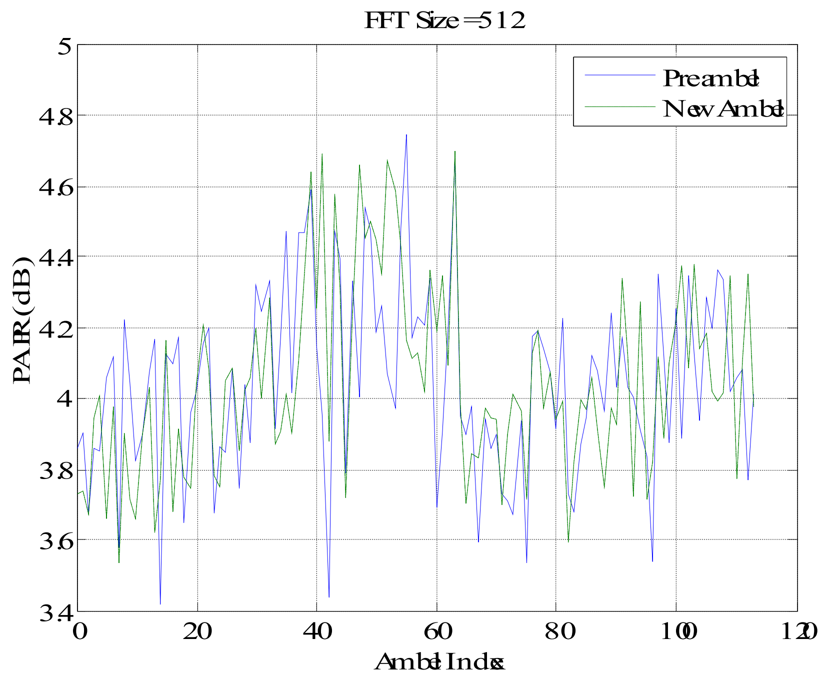

Fig. 1c PAPR performance for relay amble series (FFT size = 512)

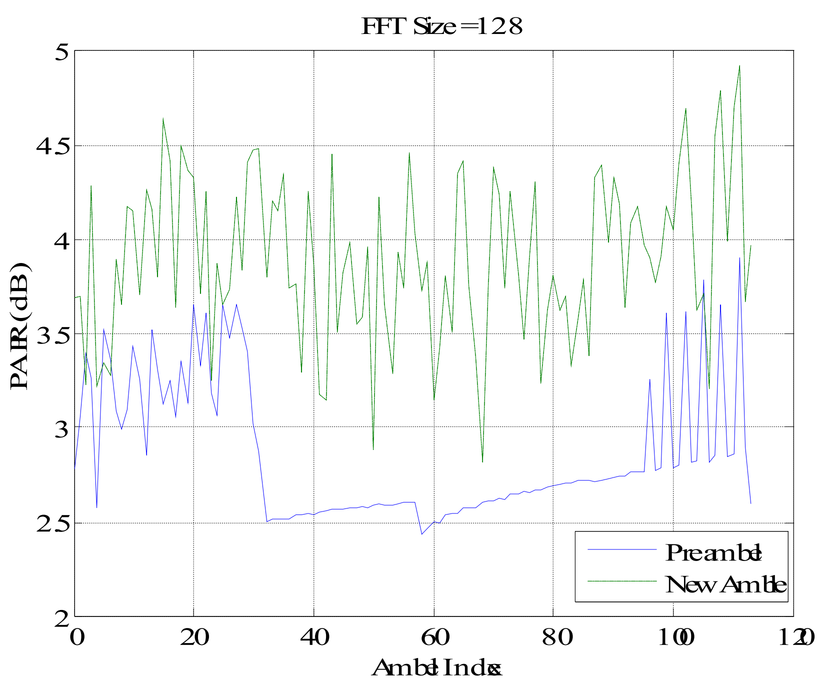

Fig. 1d PAPR performance for relay amble series (FFT size = 128)

It appears that the PAPR performance for the proposed Amble set is slightly better than that of the original preamble series for FFT size of 2048, 1024 and 512. The PAPR performance for new Amble set is worse than that for the preamble series by about 1 dB when FFT size is 128. The maximum and mean value PAPR (of all 114 ambles) for the proposed Amble series is compared with those for the preamble series in Table 1.

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

Ambles	Maximum PAPR (dB)				Mean PAPR (dB)			
	2048	1024	512	128	2048	1024	512	128
Preamble	4.91	4.49	4.75	3.90	4.58	4.07	4.05	2.86
Relay Ambles	4.89	4.44	4.70	4.92	4.58	4.08	4.04	3.90

4.2 Cross-Correlation Performance of Relay Amble Series

It is easy to verify that the proposed amble series have exactly the same cross-correlation performance as that for the original preamble series, since the new amble series is the either the reverse version or the circle-shifted version of the corresponding preamble series.

4.3 Cross-Correlation between Relay Amble and Preamble Series

The normalized cross-correlation (by the auto-correlation) between A-Amble and the Preamble series is illustrated in Fig. 2a – 2d for FFT size of 2048, 1024, 512 and 128, respectively.

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.

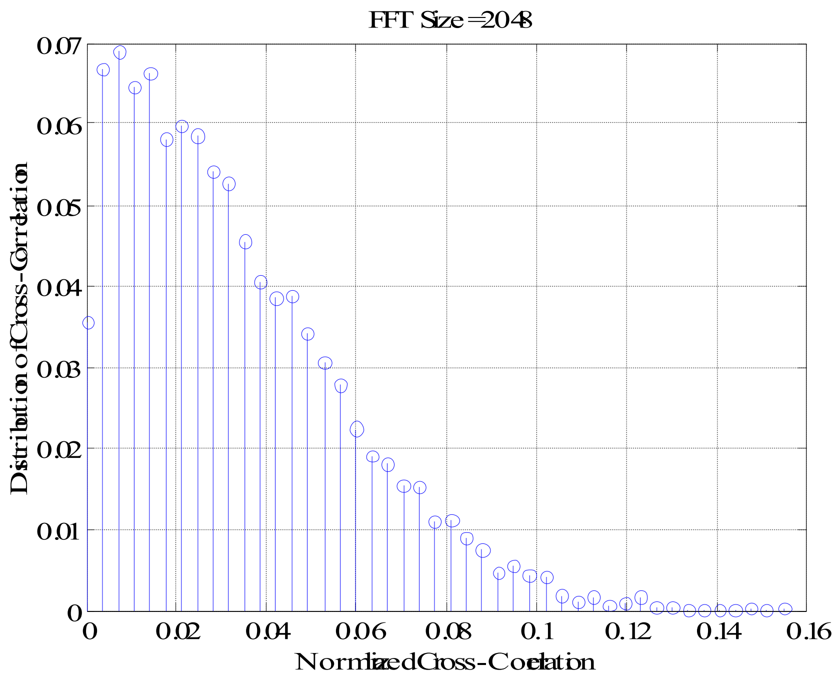

Fig. 2a Distribution of the cross-correlation between relay amble and preamble series (FFT size = 2048)

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.

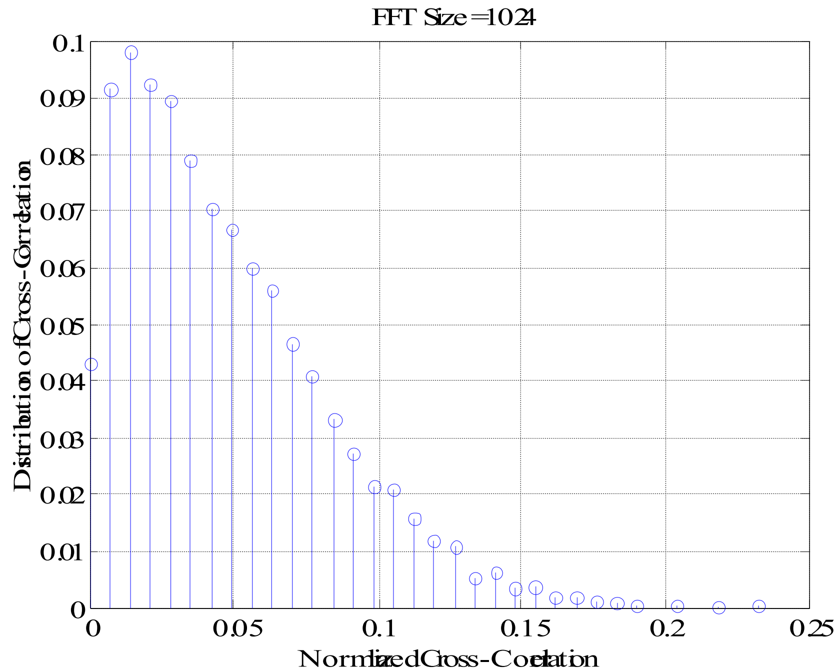

Fig. 2b Distribution of the cross-correlation between relay amble and preamble series (FFT size = 1024)

For FFT size of 512, the maximum cross-correlation between the two amble sets degrades to 0.319, which is still good enough. Note that the maximum cross-correlation among preambles is 0.444 for FFT size of 128. Even for a cross-correlation of 0.319, it still provides $20\times\log_{10}(1/0.319) = 10$ dB discrimination between the interfering amble pairs.

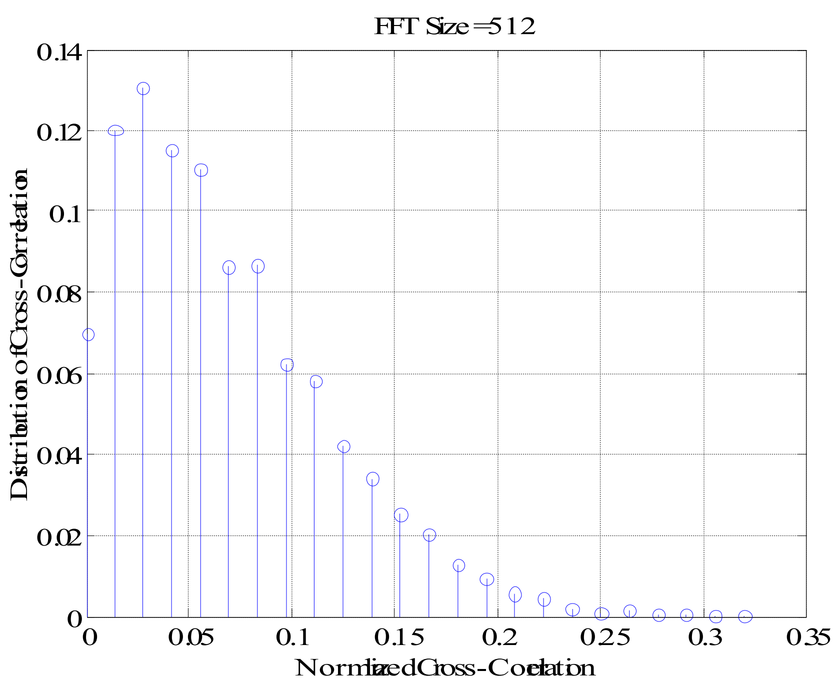

Fig. 2c Distribution of the cross-correlation between relay amble and preamble series (FFT size = 512)

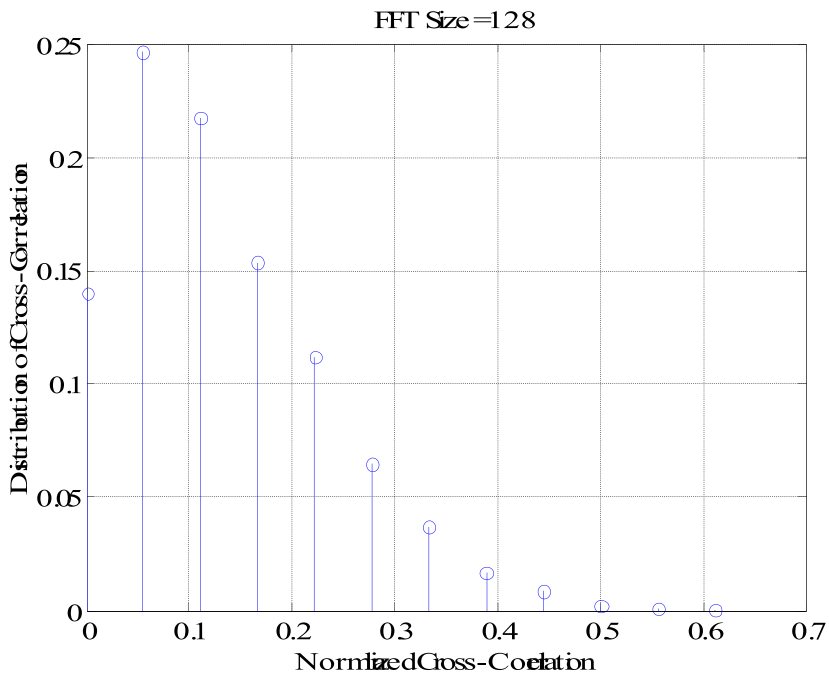

Fig. 2d Distribution of the cross-correlation between relay amble and preamble series (FFT size = 128)

The maximum cross-correlation between the two amble sets degrades to 0.611 for FFT size of 128, which is still acceptable. Even for a cross-correlation of 0.611, it still provides $20\times\log_{10}(1/0.319) = 4.3$ dB discrimination between the interfering amble pairs. Another 1 dB power backoff for the relay amble set is recommended for FFT size of 128. The 3 dB power backoff will not only mitigate false preamble detection problem satisfactorily [$4.3+3 > 7.1 = 20\times\log_{10}(1/0.611)$], but also solve the PAPR degradation automatically.

The maximum cross-correlation among the two amble sets is summarized in Table 2.

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

FFT Size	2048	1024	512	128
Maximum cross-correlation of Preambles	0.166	0.162	0.236	0.444
Maximum cross-correlation between amble sets	0.154	0.232	0.319	0.611

5. Conclusions

A new amble set 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 relay 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
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

for FFT size of 2k, 1k, and 512. For FFT size of 128, the PAPR of the new amble series is 1 dB worse than that of the 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

6. Specific text changes

Insert new subclause 8.4.6.1.1.3:

8.4.6.1.1.3 Relay amble

For FFT size of 2048 and 1024, the relay amble series $PN_i^R, i \in 0,1,\ldots,113, j \in 0,1,\ldots,J$ shall be obtained by reversing the corresponding preamble series in 8.4.6.1.1, i.e.

$$PN_i^R(j) = PN_i(J-j), \quad i \in 0,1,\ldots,113, j \in 0,1,\ldots,J \qquad \textbf{Equation xxx}$$

where PN_i is the related PN sequence length with index of i, and J is 567 and 283 for FFT size of 2048 and 1024, respectively.

For FFT size of 512 and 128, the relay amble series $PN_i^R, i \in 0,1,\ldots,113, j \in 0,1,\ldots,J$ shall be obtained by circle-shifting the corresponding preamble series in 8.4.6.1.1, i.e.

$$PN_i^R(j) = \begin{cases} PN_i(j+s), & j = 0,1,\ldots,J-s \\ PN_i(j+s-J-1), & j = J-s+1,\ldots,J \end{cases} \quad i \in 0,1,\ldots,113 \qquad \textbf{Equation xxx+1}$$

where J is 143 and 35 for FFT size of 512 and 128, respectively, and s is 2 and 1 for FFT size of 512 and 128, respectively.

The index, i, of the relay amble used in each sector/cell shall be the same as that of the preamble used in the access zone.

The relay amble series shall be modulated using boosted BPSK modulation, as specified in IEEE802.16-2005 section #8.4.9.4.3.3.