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Title	R-amble Modulation Series for FFT modes 2K, 1K and 512	
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Re:	A response to a Call for Technical Proposal, http://wirelessman.org/relay/docs/80216j-07_007r2.pdf	
Abstract	In this contribution, we propose a simple design method for R-amble modulation series.	
Purpose	To incorporate the proposed text into the P802.16j Baseline Document (IEEE 802.16j-06/026r2)	
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R-amble Modulation Series for FFT modes 2K, 1K and 512

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1. Introduction

In [1], we introduce a R-amble to be transmitted periodically for the purposes of

- Downlink synchronization ([1, Nortel] , [2, Fujitsu]): RS(s) transmitting their own preambles will not be able to receive the 802.16d/e preamble for synchronization
- Enabling the RS(s) and BS(s) to monitor the RS(s) and BS(s) in their coverage areas ([1, Nortel], [2, Fujitsu]).

This contribution introduces a method for designing R-amble modulation series.

2. Preamble Sequence Design

In 16d/e, for each OFDM size, 114 preamble sequences are provided to be transmitted at the beginning of each frame. These sequences have good auto-/cross-correlation properties and they result in low PAPRs.

Adopting the same preamble sequences with the same modulation scheme for the R-amble transmission is not possible since the MS/SS may confuse this amble with the frame-start preamble during network entry and synchronization. Therefore, we need to have new preamble sequences that are transparent to the mobile. To that hand, it is necessary to design R-amble sequences which have good auto-/cross- correlation levels within themselves, and low cross-correlation levels with the current preamble sequences. It is also required that these new sequences result in low PAPR.

One can resort to several approaches to design new sets of sequences with the desired properties. Examples to design techniques include (but certainly not limited to)

- random search,
- some method using current preambles, a 16d/e PRBS generator, and a tone-reservation method for PAPR reduction,
- using the same set of preamble sequences with a different power boosting from the 16e standard,
- etc..

Using the same set of preamble sequences is a pragmatic method, but in the presence of fast fading, the channel may change considerably from frame-start preamble to the R-amble location if they are not closely located in time; thereby reducing the effect of power level difference that could be used on the MS/SS side.

Combination of PAPR reduction techniques with preamble/PRBS generator based design is too complex and it may result in totally different preambles with the change of PRBS/tone reservation schemes.

A computer search may generate sequences with the desired properties; however, we need to create new tables for the R-amble sequences, which may significantly increase the burden of the standard text.

In this contribution, we propose a R-amble design method which generates new set of sequences by simply circularly shifting the current preambles by some offset. With the same offset for all sequences, the cross- and auto-correlation performance of the new preamble set remains the same as the original set. Since the resulting sequences are also pseudo-random sequences, their cross-correlations with the current preambles are also low. Finally, the PAPR can be lowered by an optimized selection of the offset parameter.

3. Details of the Proposed Design

Let $\mathbf{u}_k = \left[u_{k0}\ u_{k1} \ldots u_{k,L\text{-}1}\right]$ denote the k^{th} binary sequence, $k = 0,1,\ldots,113$, where L is the length of the sequence. Shifting this sequence by o_k bits, we obtain the new sequences $\mathbf{v}_{k,o_k} = \left[u_{k,L-o_k}\ u_{k,L-o_k+1} \ldots u_{k,L-1}\ u_{k,0}\ u_{k,1} \ldots u_{k,L-1-o_k}\right]$. If the offset is fixed for all $k = 0,1,\ldots,113$, e.g., $o_k = l$, then we have $\mathbf{u}_k^T \mathbf{u}_j = \mathbf{v}_k^T \mathbf{v}_j$ for all k, j pairs; hence we have the same auto- and cross-correlation levels. The cross correlation between current and new sequences, $\mathbf{u}_k^T \mathbf{v}_j$ may degrade slightly. In Figures 1.a, 2.a and 3.a, we plot the maximum cross-correlation values defined by

$$\rho_l = \max_{k,j} \frac{\mathbf{u}_k^T \mathbf{v}_{j,l}}{\left\|\mathbf{u}_k\right\|^2}$$

for various FFT sizes. We also include the maximum cross-correlation value for the original sequence, e.g., offset equals 0.

As an example, consider 1K FFT mode. With an offset value of 1 bit, the maximum cross correlation is $\rho_1 = 0.2324$. For this offset value, in Figure 1.b, we plot the PAPR values[1] for each preamble sequence generated. On the average, we observe about 0.32 dB increase in PAPR. The difference between the peak PAPR values is only 0.37 dB. Similar results for FFT modes 2K and 512 can be seen from Figures 2 and 3.

Table 1 provides the peak PAPR, mean PAPR (over all preamble sequences) and maximum cross-correlation values for the cases presented in Figures 1, 2 and 3. In these three modes of operation, we observe that modulation series generated by circular shifts on the original sequences provide acceptable performance in both correlation and PAPR levels. The design for FFT mode 128 is FFS.

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[1] The modulation of the binary sequences is described in 802.16d/e Sections 8.4.6.1.1 and 8.4.9.4.3.1.

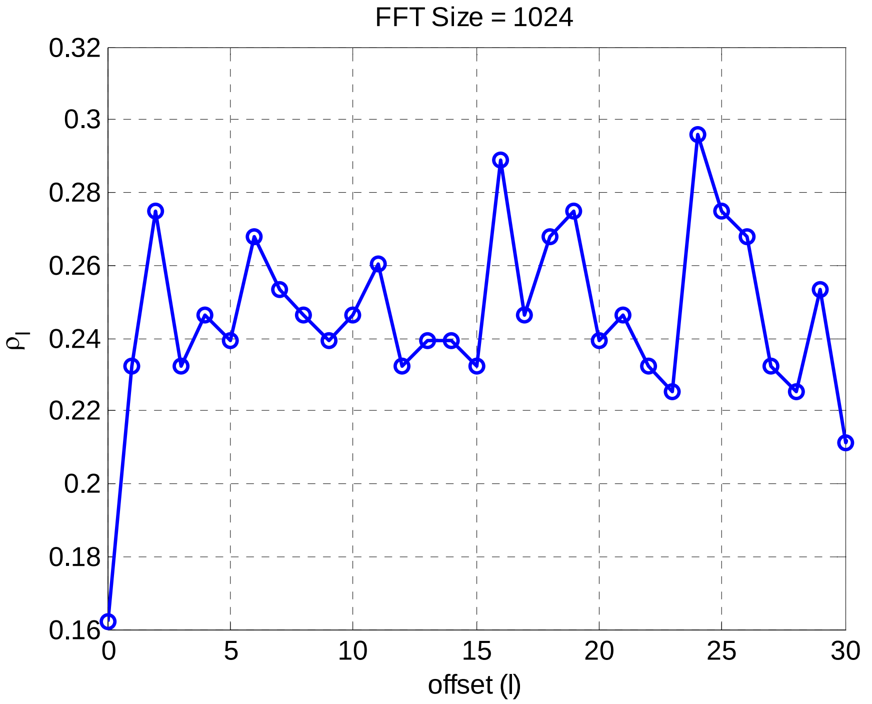

Figure 1.a Maximum cross-correlation for different offset values. OFDM Size = 1024.

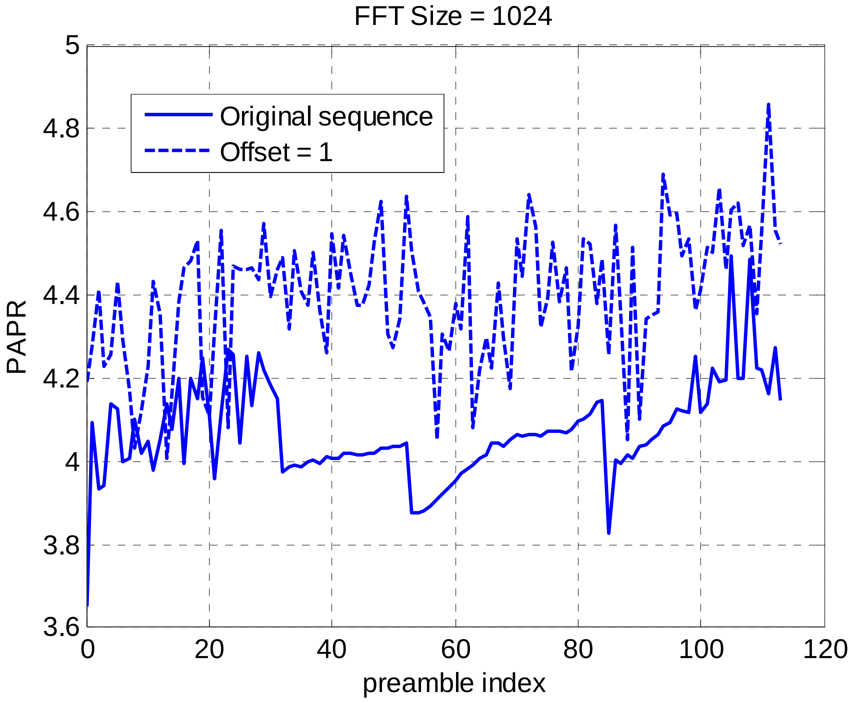

Figure 1.b PAPR for offset = 1, OFDM Size = 1024.

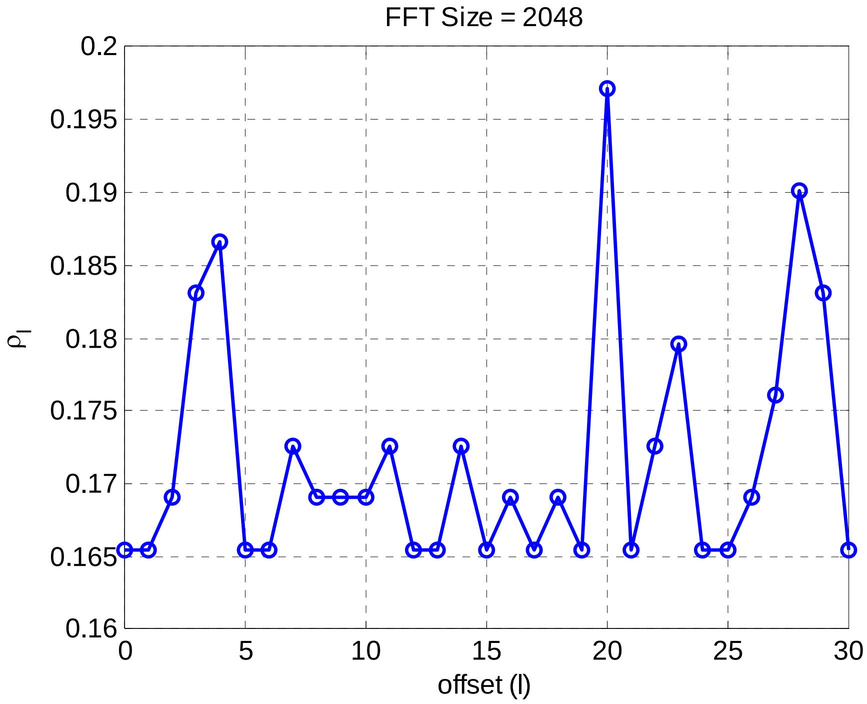

Figure 2.a Maximum cross-correlation for different offset values. OFDM Size = 2048.

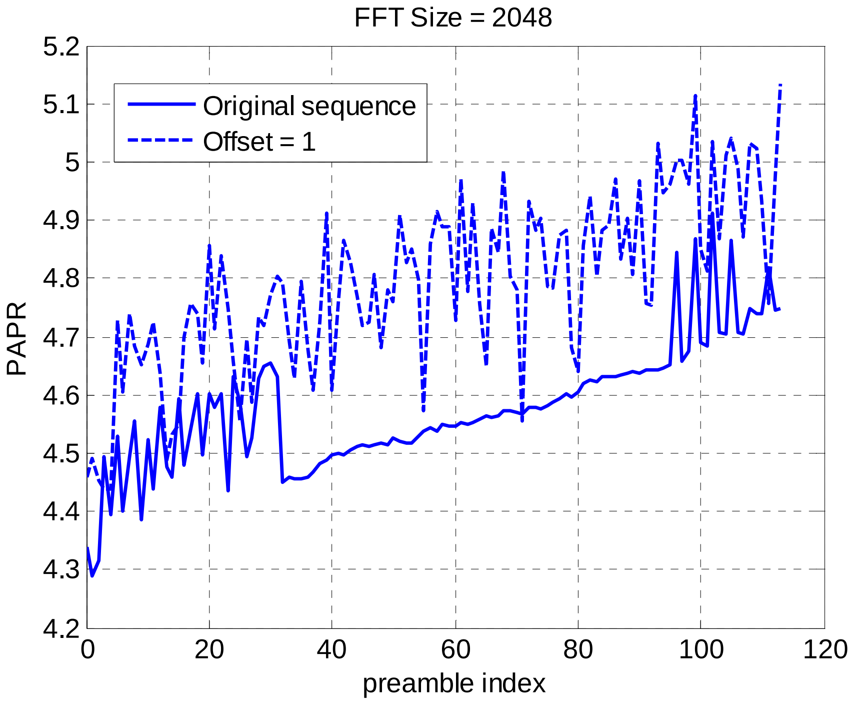

Figure 2.b PAPR for offset = 1, OFDM Size = 2048.

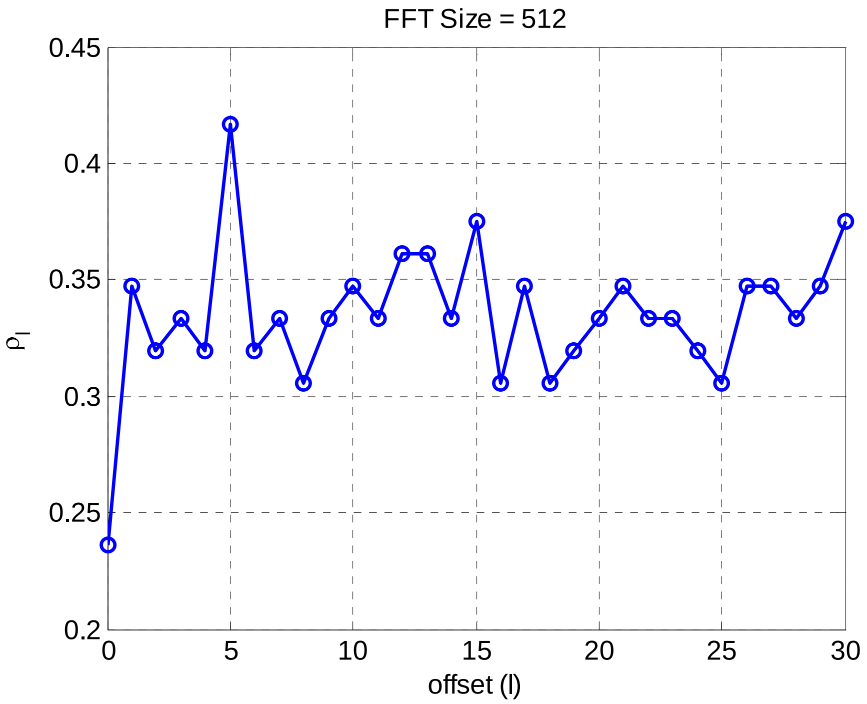

Figure 3.a Maximum cross-correlation for different offset values. OFDM Size = 512.

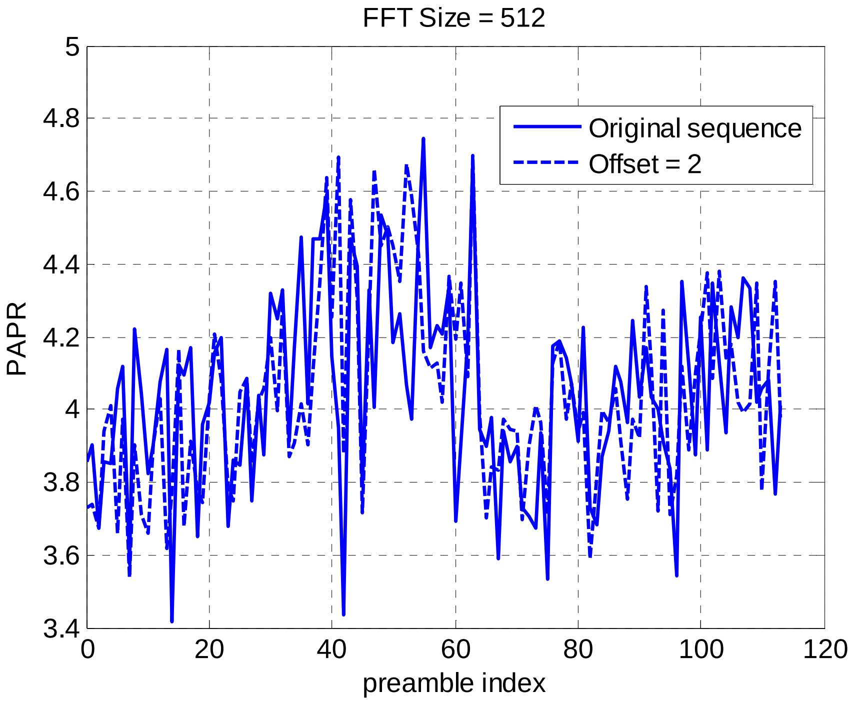

Figure 3.b PAPR for offset = 2, OFDM Size = 512.

Table 1 PAPR and maximum cross-correlation values. The first and second numbers (in the parentheses) indicate the values obtained with sequences 16e, and with the sequences designed by the proposed technique, respectively.

FFT Size	Peak PAPR (dB)	Mean PAPR (dB)	Max. cross-correlation	Offset
2048	(4.9, 5.1)	(4.6, 4.8)	(0.17,0.17)	1
1024	(4.5,4.9)	(4.0,4.4)	(0.16, 0.23)	1
512	(4.74,4.7)	(4,4)	(0.23,0.32)	2

3. Proposed Text Change

Insert new subclause 8.4.6.1.1.2:

For 2K, 1K and 512 FFT modes, the R-amble sequences shall be obtained by a bit-wise right-circular shift of the preamble sequences provided in Tables 309-309c by the offset values given in Table 309d. The R-amble index assignment shall be the same as given in Tables 309-309c, and the RS shall use the same index for both frame-start preamble and the R-amble.

Insert Table 309d:

OFDM Size	Offset
2048	1
1024	1
512	2
128	FFS

References

[1] Hang Zhang, et al., IEEE C802.16j-06/240 "RS DL Synchronization and Radio Environment Measurement - Introduction of RS-Preamble", available at http://www.ieee802.org/16/relay/contrib/C80216j-06_240.pdf

[2] Mike Hart, et al., IEEE C802.16j-06/144, "Relay midamble", available at http://www.ieee802.org/16/relay/contrib/C80216j-06_144.pdf