# A novel low PAPR preamble for very high throughput WLAN IEEE 802.11ac 80MHz system

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# A Novel Low PAPR Preamble for Very High Throughput WLAN IEEE 802.11ac 80MHz System

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**Abstract.** This paper proposes a novel low peak to average power ratio (PAPR) preamble to be used in very high throughput WLAN IEEE 802.11ac 80 MHz system. Partial transmit sequence technique was exploited to obtain a novel phase rotation set. Implementing this phase rotation set into 80 MHz system of the VHT WLAN IEEE802.11ac's preamble reduced the PAPR of the signal, significantly. It was 1. 4 dB lower than the PAPR of conventional extension of IEEE 802.11ac 80 MHz and even 1.6 dB lower than the PAPR of HT WLAN IEEE802.11n 40MHz.

## INTRODUCTION

The recent wireless LAN (WLAN) systems should have ability to support copious applications in wireless communication. This leads to a combination of the orthogonal frequency division multiplexing (OFDM) and multiple-input multiple-output (MIMO) techniques to provide a very high throughput.

The IEEE802.11ac which is called very high throughput (VHT) WLAN system provides Giga bit per second of throughput at the medium access control layer [1]. It offers throughput up to 3.466 Gbps by eight spatial streams with 234 subcarriers within 80 MHz of bandwidth and 256-QAM digital symbol in each subcarrier. It also promises high resolution for both narrow and medium bandwidth channels. A study to improve the performance of VHT WLAN IEEE 802.11ac was presented in [2].

The VHT WLAN IEEE 802.11ac operates in the 5 GHz frequency band same as the formers WLAN IEEE802.11a/n therefore coexistence of the systems were included in it's functional requirements. Those systems above take advantage of using OFDM to provide high throughput and the IEEE802.11n/ac employ MIMO to boost the throughput and performance. However, as an OFDM-based system they suffer from peak-to-average-power-ratio (PAPR) problem. From those three, IEEE802.11ac shall experience the highest PAPR problem due to using the largest number of subcarriers.

Many PAPR reduction techniques for OFDM System, such as amplitude clipping, filtering, coding, tone reservation (TR), tone injection, active constellation extension, and multiple signal representation techniques such as partial transmit sequence (PTS), selected mapping (SLM), and interleaving were discussed and compared in [3]. Those techniques reduce the PAPR by the cost of transmit signal power increase, bit error rate (BER) increase, computational complexity increase, data rate loss, and so on. The discussion was ended with statement that there is no the best technique to lower the PAPR problem for all OFDM systems. The technique should be carefully chosen to match the system requirement.

More modern technique to reduce PAPR of the OFDM system was circulant shift codeword. The key idea was generating scramble data sequences. Simulation results showed that the proposed technique gave 1.1 dB lower PAPR with lower complexity and lower number of IFFT blocks than the conventional SLM. [4].

A combination of TR and Clipping (CL) method to improve the PAPR reduction while maintaining the quality of transmissions of MIMO-OFDM system was proposed in [5] . The gain provided by this strategy was compared to

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classical methods. It allows to envisage an improvement in energy balance sheet of the amplification stage. It was claimed that the spectrum of the generated signals fulfilled the requirement of the WiMax IEEE 802.16 standard.

Nonlinear companding transform was used to reduce the PAPR of OFDM systems. However, it comes with serious nonlinear distortion or complex companding parameters optimization embarrassment. Therefore a designing criterion of nonlinear companding functions with more effective system performance was proposed. It was able to get a lower PAPR, lesser out-of-band radiation, and simpler companding parameters optimization than the conventional one. Numerical results showed that the companding schemes which follow the proposed criterion outperform the conventional schemes. [6]

Instead of using PTS and SLM technique to reduce the high PAPR of Multicarrier code division multiple access (MC-CDMA) systems, NORM technique was proposed. Simulation results showed that NORM has better PAPR reduction with less computational complexity than PTS and SLM technique. [7]

Enhancing the PAPR and Inter Carrier Interference in MIMO-OFDM system by inserting Residual Number (RNS) coding was proposed in [8]. It was shown that the proposed technique was able to improve the communication system features by decreasing the ICI and improving the BER performance.

The HT WLAN IEEE802.11n 40 MHz system implements PTS technique to reduce the PAPR of the generated OFDM signals. By rotating the logical positive frequencies by 90 [deg] relative to the negative ones, the PAPR of 40 MHz signals are reduced with low complexity procedure. However, applying this procedure in conventional VHT WLAN IEEE802.11ac 80 MHz system generates high PAPR signals.

This paper presents a novel low PAPR preamble for VHT WLAN IEEE 802.11ac. It came from implementing phase rotation set onto 80 MHz system which were derived from the modified PTS technique. Backward compatibility to the former WLAN IEEE802.11a/n systems to ensure coexistence of the systems also have been taken into consideration. The rest of this paper is organized as follows. The VHT WLAN IEEE 802.11ac is briefly introduced in Section II. The development of a novel low PAPR preamble which was derived using modified PTS are explained in Section III, as well as the comparison of PAPR between the existing WLANs. Finally, some conclusions and future works are drawn in Section IV.

## VERY HIGH THROUGHPUT WIRELESS LAN IEEE 802.11AC 80 MHZ SYSTEM

To achieve very high throughput, the VHT WLAN IEEE 802.11ac might extend the bandwidth to 80MHz. Mixed format (MF) preamble is used by this system to ensure it's backward compatibility to the formers WLAN IEEE802.11a/n systems. MF preamble consists of three main fields, short training fields (STFs), long training fields (LTFs) and SIGNAL fields (SIGs) of legacy (L) and very high throughput (VHT) fields. The legacy fields will be decoded by the former WLAN IEEE802.11a devices as well as by HT WLAN 802.11n devices while VHT fields only can be decoded by VHT WLAN IEEE 802.11ac devices. Time domain representation of MF preamble of VHT WLAN IEEE 802.11ac 80 MHz for single spatial stream is shown in **FIGURE 1**. [1]

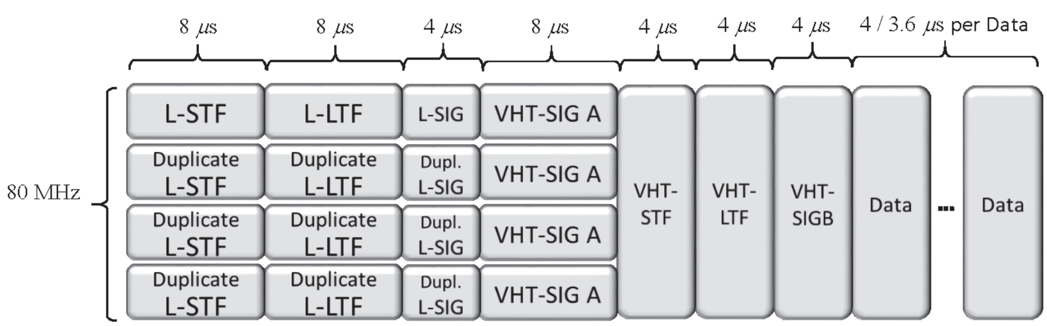



**FIGURE 1.** Time domain representation of mixed format preamble of VHT WLAN IEEE 802.11ac, 80 MHz bandwidth, 1 $N_{STS}$. Mixed format preamble is used to ensure backward compatibility of IEEE 802.11ac to IEEE802.11a/n.

### Configuration of Conventional VHT WLAN IEEE 802.11ac 80MHz System

HT WLAN IEEE802.11n system employs 128 subcarriers within 40MHz bandwidth. 64 subcarriers are assigned as logical negative subcarriers, i.e. $k < 0$ and placed in 20MHz lower. The rests are logical positive subcarriers which are 90° phase rotated relative to negative ones, i.e. multiplied by $e^{j\pi/2}$, to reduce the PAPR. It is called $[1 \quad j]$ configuration.

As an extension to provide very high throughput, the VHT WLAN IEEE802.11ac employs 256 subcarriers within 80MHz bandwidth. To maintain backward compatibility to WLAN IEEE802.11a and HT WLAN IEEE802.11n devices, logically 256 subcarriers 80 MHz is divided into four sub blocks, each 64 subcarriers within 20MHz. In conventional extension configuration, the first two blocks, called 40 MHz lower, are phase rotated using the same phase rotation as implemented in HT WLAN IEEE802.11n 40 MHz, i.e. $[1 \quad j]$. The second two blocks (40 MHz upper) are treated the same. This conventional configuration of phase rotation for VHT WLAN IEEE802.11ac 80 MHz is expressed in (1) where $\gamma_k$ denotes the phase rotation of the subcarrier $k$ and illustrated in **FIGURE 2**.

$$\gamma_k \begin{cases} 1 & k \le -64 \\ j & -64 < k \le 0 \\ 1 & 0 < k \le 64 \\ j & k > 64 \end{cases} \tag{1}$$

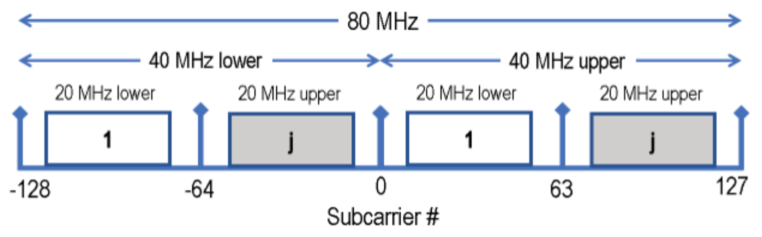



**FIGURE 2.** Conventional configuraton of phase rotation of the four blocks of subcarriers of VHT WLAN IEEE 802.11ac 80 MHz. Each block consists of 64subcarriers within 20 MHz of bandwidth were multiplied by phase rotation set [ 1 j 1 j ].

Unfortunately, after calculating the PAPR of the generated preamble signal, this conventional configuration of phase rotation for 80MHz produced high PAPR signal. **TABLE 1** lists the PAPR value of each field of the preamble of HT WLAN IEEE802.11n and conventional configuration of VHT WLAN IEEE802.11ac.

**TABLE 1.** PAPR value of each field of the preambles

| Field | IEEE 802.11n 40MHz (dB) | IEEE 802.11ac 80 MHz (dB) |
|---|---|---|
| L – STF | 5.25 | 5.82 |
| L – LTF | 6.01 | 6.69 |
| HT / VHT – STF | 5.25 | 5.82 |
| HT / VHT – LTF | 6.36 | 7.10 |

## A NOVEL LOW PAPR PREAMBLE FOR VHT WLAN

To reduce the PAPR of the preamble, partial transmit sequence technique is exploited. However without modification this PTS technique may break the backward compatibility requirement of VHT WLAN IEEE802.11ac to the formers WLANs, IEEE802.11a/n systems. Bellows are brief review of the modified PTS technique that produced a novel phase rotation set to obtain low PAPR preamble for VHT WLAN IEEE802.11ac 80MHz system. This techniques has been published in [9] and patented in [10].

### Configuration of the proposed 80MHz System

In our proposal the number of IFFT point, N, is 256; number of sub vectors, M, is four, i.e., 1st, 2nd, 3rd, and 4th of 20 MHz Subcarriers on the 2nd 20 MHz are 90 [deg] phase rotated relative to the 1st 20 MHz The subcarriers on the 3rd and 4th of 20 MHz are phase rotated by multiplication with $e^{j\theta 1}$ and $j^{e\theta 2}$, respectively. This configuration is expressed in (9) and illustrated in Fig. 4. The signal is then oversampled four times ($L$ = 4) and frequency shifted before entering the oversized IFFT. Four times oversampling is done by padding (L − 1) × N/2 zeros at the front and the rear of the signal. PAPR is calculated from time domain OFDM signal as an output of oversized N × L IFFT.

$$\gamma_{k}= \begin{cases} 1 & k \leq -64 \\ j & -64 < k \leq 0 \\ e^{j\theta 1} & 0 < k \leq 64 \\ je^{j\theta 2} & k > 64 \end{cases} \tag{2}$$

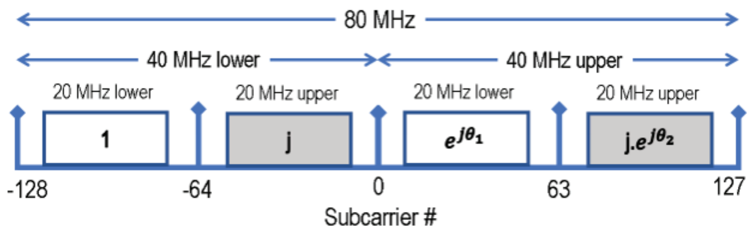
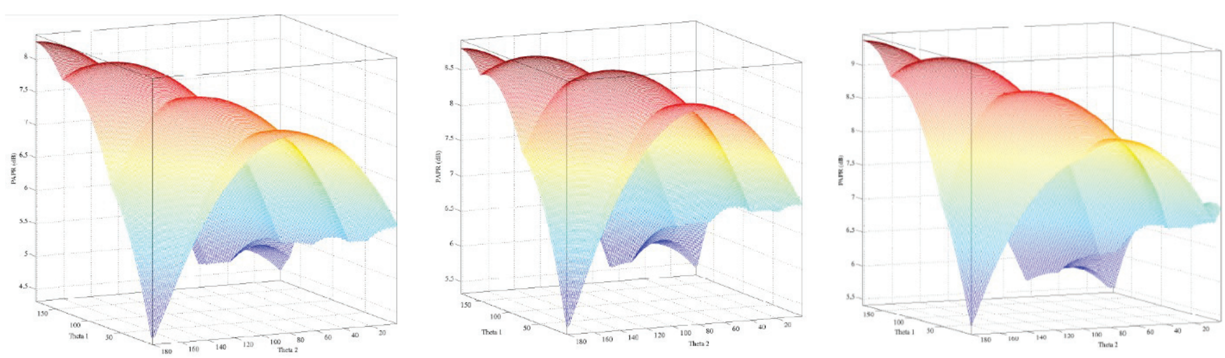



**FIGURE 3.** Configuration of subcarriers when searching the optimal phase rotation of the four blocks of subcarriers of VHT WLAN IEEE 802.11ac 80 MHz using a modified PTS technique. Each block consists of 64 subcarriers within 20 MHz of bandwidth were multiplied by phase rotation set.

As employing the modified PTS technique, the aim were searching the set value of $\theta_1$ and $\theta_2 \in [0, 180]$ that gave the lowest PAPR for each L-STF, L-LTF, VHT-STF and VHT-LTF. This step required high complexity calculation. The searching process for the best set value of $\theta_1$ and $\theta_2$ to obtain lowest PAPR of L-STF and VHT-STF, L-LTF, and VHTLTF are shown in Fig. 5, 6, and 7, respectively. Where X-axis is the value of $\theta_1$, Y-axis is the value of $\theta_2$ and Z-axis is the obtained PAPR in dB. It was found that the lowest PAPR of L-STF and VHT-STF was 4.42 dB with $\theta_1$= 1 [deg] and $\theta_2$= 179 [deg], the lowest PAPR of L-LTF was 5.43 dB with $\theta_1$= 0 [deg] and $\theta_2$= 180 [deg], and the lowest PAPR of VHT-LTF was 5.57 dB with $\theta_1$ = 2 [deg] and $\theta_2$ = 180 [deg].



(a) (b) (c)

**FIGURE 4.** Searching phase rotation set for the lowest PAPR using modified PTS technique (a) L-STF and VHT-STF, obtained 4.42 dB for $\theta_1$= 1 [deg] and $\theta_2$ = 179 [deg]. (b) L-LTF, obtained 5.43 dB for $\theta_1$= 0 [deg] and $\theta_2$ = 180 [deg], (c) VHT-LTF, obtained 5.57 dB for $\theta_1$1 = 2 [deg] and $\theta_2$ = 180 [deg].

By considering those results and practical aspect to reduce the complexity and eliminating the need of side information transmission, fixed phase rotation set value for all field was proposed as $\theta_1$ = 0 and $\theta_2$ = 180 which expressed by (3) and depicted in Fig. 8. This novel configuration was applied to all fields of the preamble.

$$\gamma_{k} = \begin{cases} 1 & k \leq -64 \\ j & -64 < k \leq 0 \\ 1 & 0 < k \leq 64 \\ -j & k > 64 \end{cases} \quad (3)$$

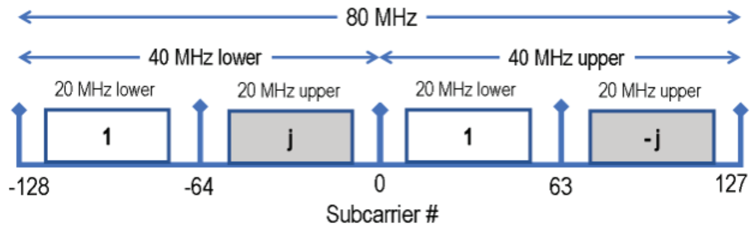



**FIGURE 5.** Proposed configuraton of phase rotation set of the four blocks of subcarriers of VHT WLAN IEEE 802.11ac 80 MHz. Each block consists of 64 subcarriers within 20 MHz of bandwidth were multiplied by phase rotation set [ 1 j 1 - j ].

**TABLE 2** lists the obtained PAPR of the fields of the preamble of the VHT WLAN IEEE 802.11ac 80MHz system using conventional and proposed configuration. In the first column the PAPR of HT WLAN IEEE802.11n 40MHz system was put for comparison. All values are obtained from oversized IFFT with four-time oversampled input. This table shows that the proposed configuration significantly reduced the PAPR of the signal to be the lowest PAPR. It was 1.4 dB lower than the PAPR of conventional extension and even lower than the PAPR of HT WLAN IEEE802.11n 40MHz system, though it had twice number of subcarriers. The PAPR of SIG fields and Data fields were not shown here since their value were varying depend on the contained information.

**TABLE 2.** PAPR Comparison of The Preambles

| **Field** | **IEEE 802.11n 40MHz (dB)** | **IEEE 802.11ac 80 MHz** | |
|---|---|---|---|
| | | **Conv. Extension (dB)** | **Novel Phase Rotation (dB)** |
| L – STF | 5.25 | 5.82 | 4.47 |
| L – LTF | 6.01 | 6.69 | 5.43 |
| HT / VHT – STF | 5.25 | 5.82 | 4.47 |
| HT / VHT – LTF | 6.36 | 7.10 | 5.57 |

## CONCLUSION

A novel low PAPR preamble for VHT WLAN IEEE802.11ac 80 MHz has been proposed. It is obtained by rotating the phase using phase rotation set which was derived from modified PTS technique. Implementing this phase rotation set into 80 MHz system of the VHT WLAN IEEE802.11ac's preamble reduced the PAPR of the signal significantly. It was 1. 4 dB lower than the PAPR of conventional extension of VHT WLAN IEEE 802.11ac 80 MHz and even 1.6 dB lower than the PAPR of HT WLAN IEEE802.11n 40MHz. Next work will be examining the backward compatibility of this low PAPR preamble to the former WLANs IEEE802.11a/n devices.

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