

Phase Rotation for the 80 MHz 802.11ac Mixed Mode Packet

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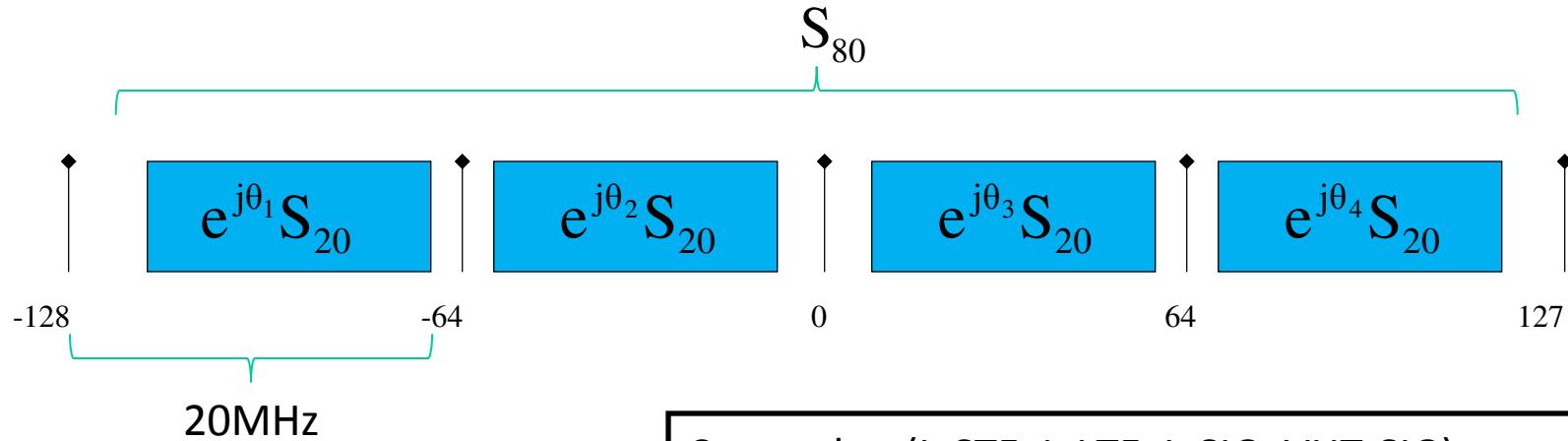
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Abstract

- In 802.11n, a phase rotation of 90 degrees was applied to the upper 20MHz band of the 40MHz packet in order to reduce the PAPR [1].
- In [2], we proposed phase rotations for every 20MHz band in the 80MHz packet that achieves the same effect.
- We will show theoretical proofs, additional simulations, and make a straw poll for our proposal

Optimal Phase Shifts (1/5)



S₂₀ can be (L-STF, L-LTF, L-SIG, VHT-SIG)
subcarrier symbol vector for the 20MHz packet
 θ_i = phase shift for the i^{th} 20MHz band

$$s_{80}(n) = \sum_{k=-32}^{31} S_{80}(k) e^{\frac{j2\pi kn}{64}}$$

$$s_{80}(n) = \sum_{k=-8}^7 S_{20}(k) e^{j\theta_1} e^{\frac{j2\pi n(k-24)}{64}} + \sum_{k=-8}^7 S_{20}(k) e^{j\theta_2} e^{\frac{j2\pi n(k-8)}{64}} + \sum_{k=-8}^7 S_{20}(k) e^{j\theta_3} e^{\frac{j2\pi n(k+8)}{64}} + \sum_{k=-8}^7 S_{20}(k) e^{j\theta_4} e^{\frac{j2\pi n(k+24)}{64}}$$

$$s_{80}(n) = \sum_{k=-8}^7 S_{20}(k) e^{\frac{j2\pi kn}{64}} \left[e^{j\theta_1} e^{\frac{j-3\pi n}{4}} + e^{j\theta_2} e^{\frac{j-\pi n}{4}} + e^{j\theta_3} e^{\frac{j\pi n}{4}} + e^{j\theta_4} e^{\frac{j3\pi n}{4}} \right]$$

Optimal Phase Shifts (2/5)

$$s_{80}(n) = \sum_{k=-8}^7 S_{20}(k) e^{j \frac{2\pi k n}{64}} \left[e^{j\theta_1} e^{\frac{j -3\pi n}{4}} + e^{j\theta_2} e^{\frac{j -\pi n}{4}} + e^{j\theta_3} e^{\frac{j \pi n}{4}} + e^{j\theta_4} e^{\frac{j 3\pi n}{4}} \right]$$

rearranging

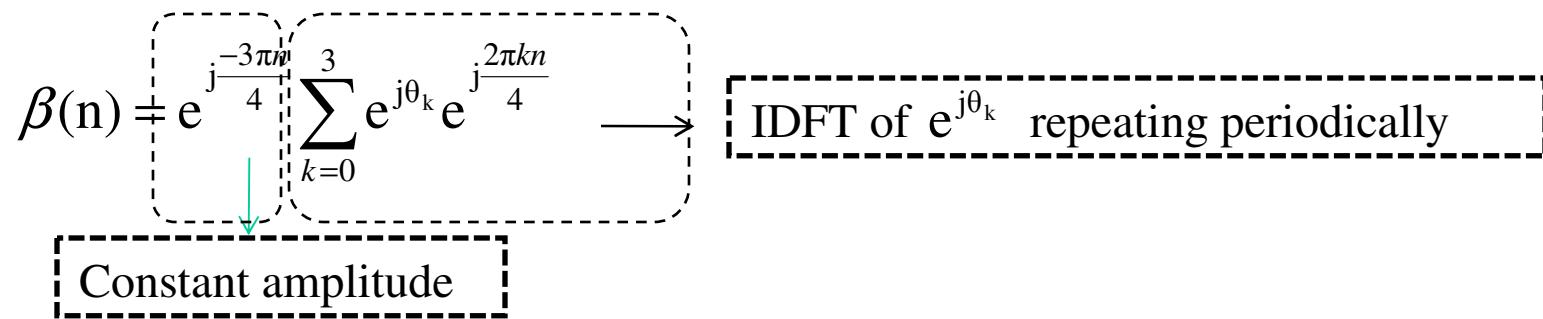
$$s_{80}(n) = \left[e^{j\theta_1} e^{\frac{j -3\pi n}{4}} + e^{j\theta_2} e^{\frac{j -\pi n}{4}} + e^{j\theta_3} e^{\frac{j \pi n}{4}} + e^{j\theta_4} e^{\frac{j 3\pi n}{4}} \right] \sum_{k=-8}^7 S_{20}(k) e^{j \frac{2\pi k n}{64}}$$


It is clear that duplication of the 20MHz subcarrier bits to 80MHz band is equal to a 4x oversampled of the 20MHz signal modulated by $\beta(n)$

Optimal Phase Shifts (3/5)

- To minimize the PAPR of $s_{80}(n)$, it is necessary to ensure unity magnitude of $\beta(n)$

$$\beta(n) = e^{j\theta_1} e^{\frac{j-3\pi n}{4}} + e^{j\theta_2} e^{\frac{j-\pi n}{4}} + e^{j\theta_3} e^{\frac{j\pi n}{4}} + e^{j\theta_4} e^{\frac{j3\pi n}{4}}$$



To minimize the PAPR of $\beta(n)$, we need to choose $e^{j\theta_k}$ whose IDFT has low PAPR

$e^{j\theta_k}$ can be chosen from any **CAZAC** (Constant Amplitude Zero Autocorrelation) sequence (e.g. Frank Zadoff Chu) to ensure unity magnitude of $\beta(n)$

Optimal Phase Shifts (4/5)

- To maintain compatibility with 40MHz legacy devices,

$$e^{j\theta_k} = [(1)e^{j\varphi_1} \quad (j)e^{j\varphi_1} \quad (1)e^{j\varphi_2} \quad (j)e^{j\varphi_2}]$$

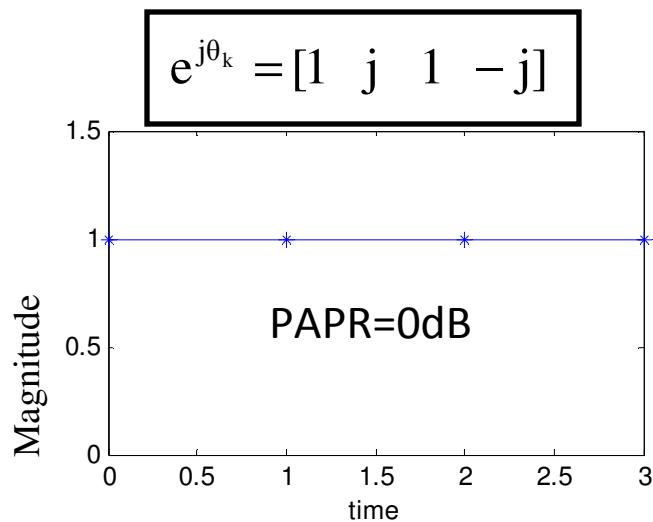
where φ_i are any phase shifts

(e.g. $e^{j\theta_k} = [1 \ j \ 1 \ j]^\top$)

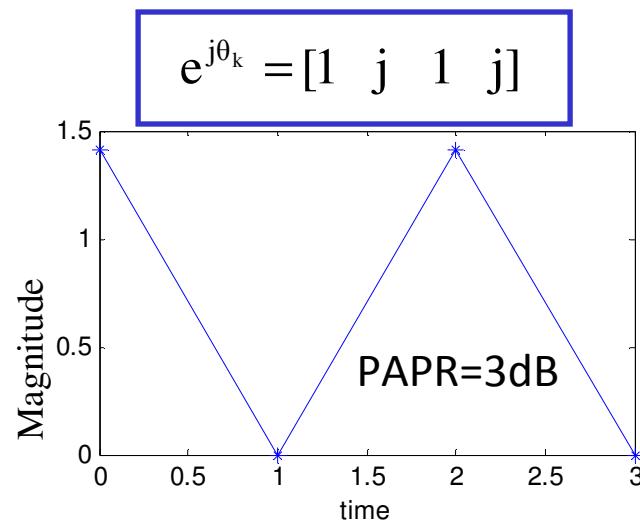
- Unfortunately, there are no CAZAC sequences of this form. The closest and easiest to implement sequence we found is

$$E = \{[1 \ j \ 1 \ -j]\} \quad \text{Including its cyclic shifts and scaled versions}$$

Optimal Phase Shifts (5/5)

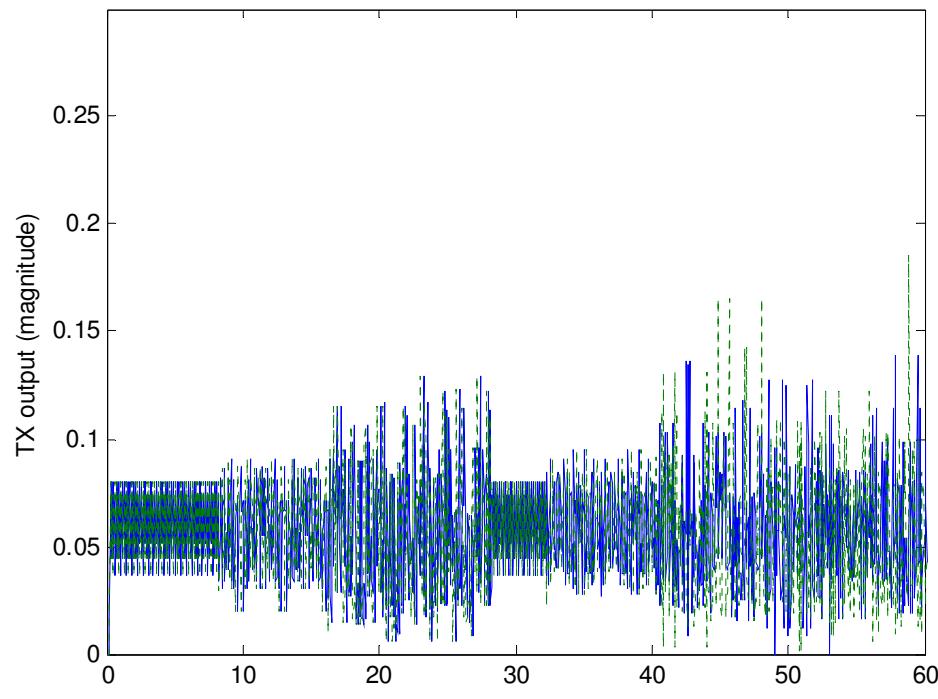


No PAPR increase from S₂₀



Expect increase of 3dB from S₂₀

Simulations Results – PAPR (1/3)



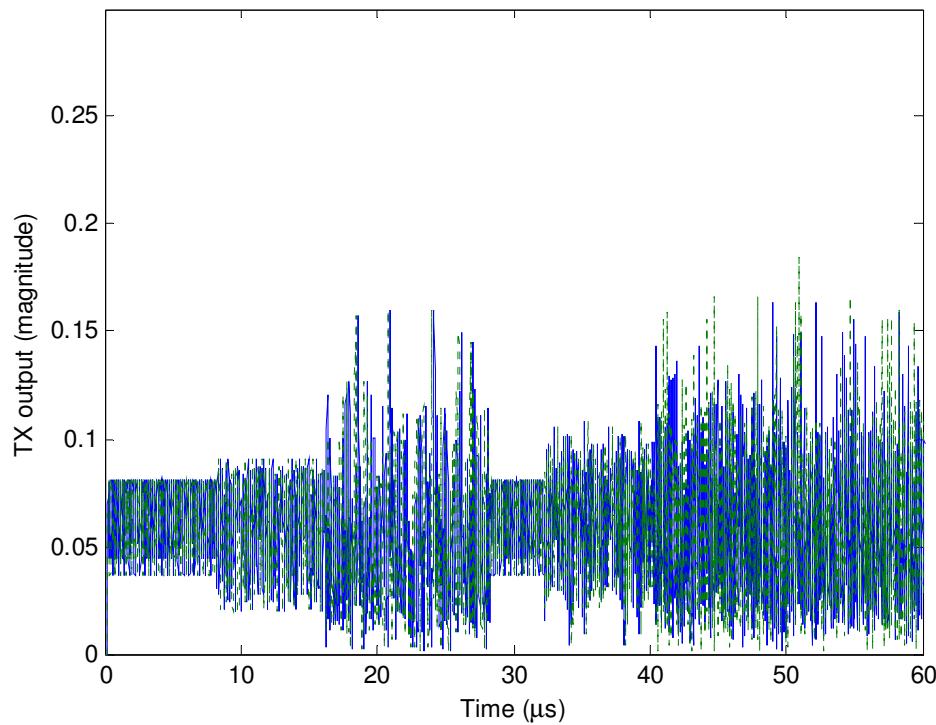
20MHz 11n Mixed Mode packet

20MHz Sampling Rate

| Fields | PAPR |
|---------|--------|
| L-STF | 2.09dB |
| L-LTF | 3.17dB |
| L-SIG | 5.28dB |
| VHT-SIG | 6.28dB |
| PACKET | 9.58dB |

Basis PAPR

Simulations Results – PAPR (2/3)



$$e^{j\theta_k} = [1 \quad j \quad 1 \quad -j]$$

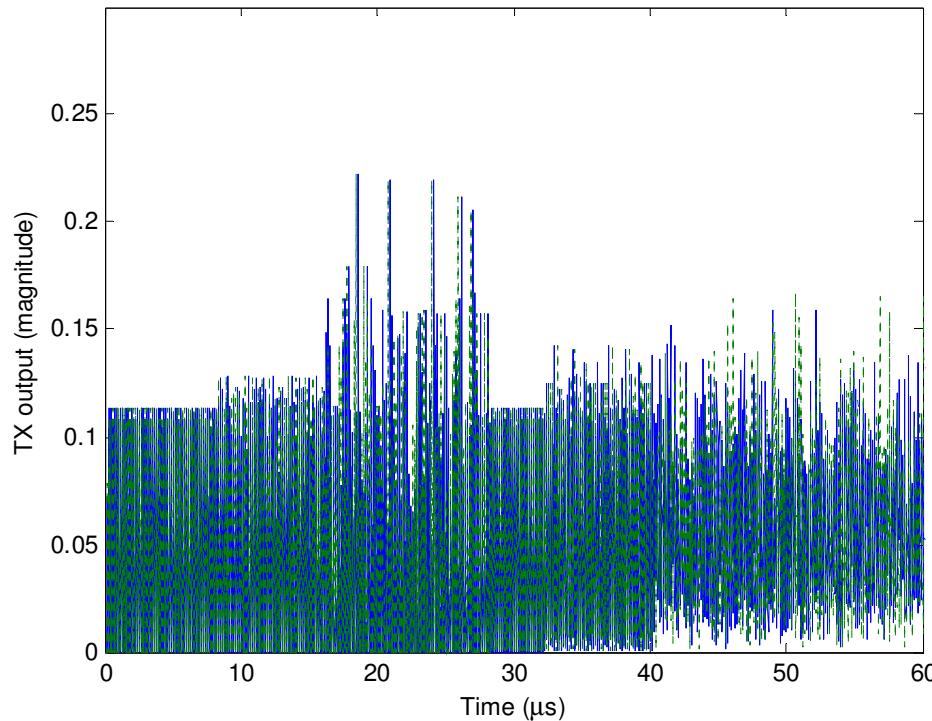
80MHz Single user 11ac Mixed Mode Packet

80MHz Sampling Rate

| Fields | PAPR |
|---------|--------|
| L-STF | 2.28dB |
| L-LTF | 3.20dB |
| L-SIG | 7.98dB |
| VHT-SIG | 8.12dB |
| PACKET | 9.34dB |

Except for the effect of oversampling for L-STF and L-LTF, change of subcarrier bits in SIG fields, the PAPR is **unchanged**

Simulations Results – PAPR (3/3)



80MHz Sampling Rate

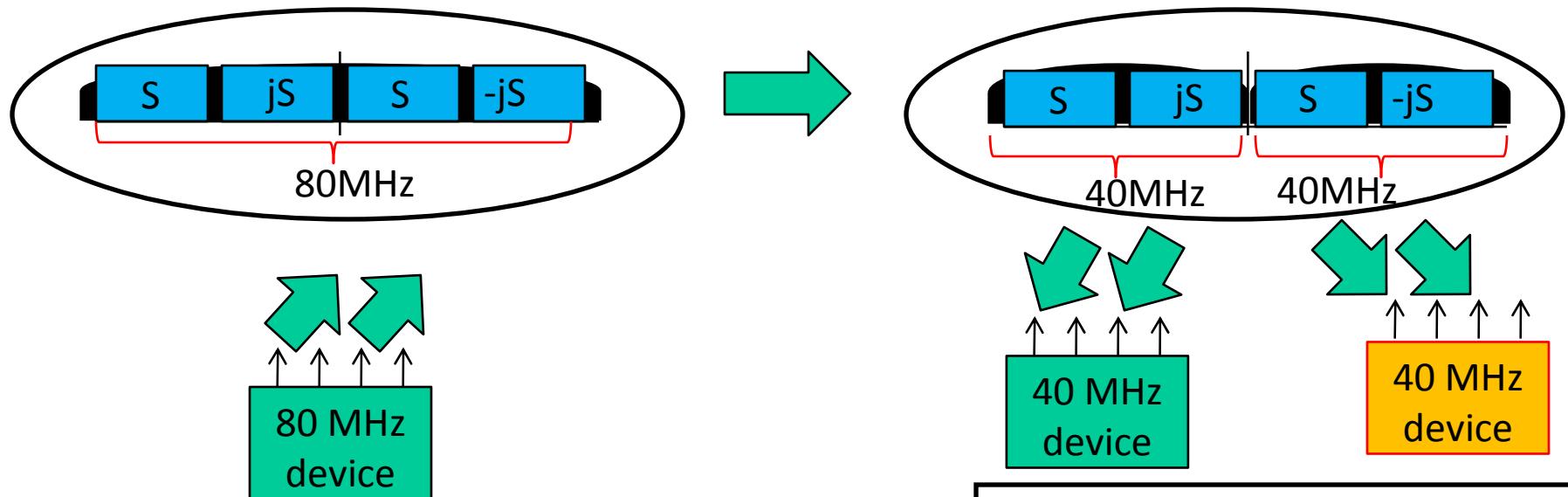
| Fields | PAPR | |
|---------|---------|-------|
| L-STF | 5.14dB | ~+3dB |
| L-LTF | 6.21dB | ~+3dB |
| L-SIG | 11dB | ~+3dB |
| VHT-SIG | 10.87dB | ~+3dB |
| PACKET | 11dB | ~+2dB |

PAPR increase due to $e^{j\theta_k}$

$$e^{j\theta_k} = [1 \ j \ 1 \ j]$$

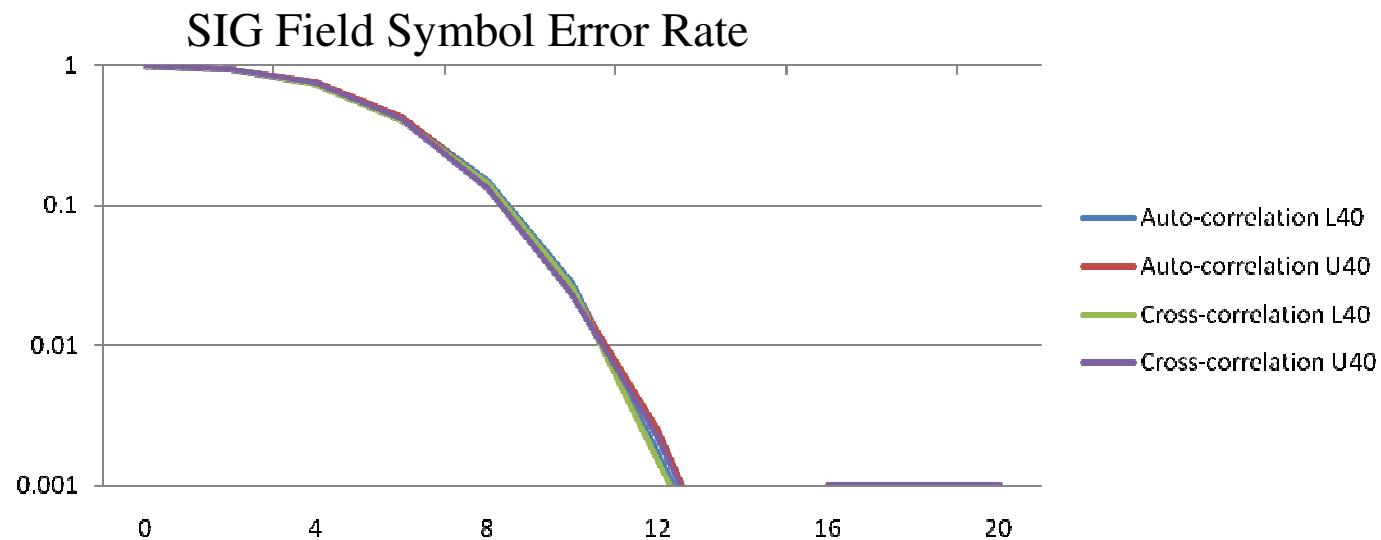
80MHz Single user 11ac Mixed Mode Packet

Simulations Results – Backward Compatibility (1/2)



11n devices at the **UPPER 40 MHz** channel expects [1 j] subcarrier rotation and has a **possible compatibility issue** when **Cross Correlation** is used for frame synchronization

Simulations Results – Backward Compatibility (2/2)



TGn Channel D
10000 iterations
Impairments: CFO, Phase noise, PA nonlinearity,

40MHz legacy devices at both sides of the 80MHz channel that uses only Frame Synchronization has similar performance

Conclusions

- In order to minimize the PAPR of the 80MHz packet, phase rotation for every 20MHz band is necessary.
- CAZAC sequences are optimal sequence for the phase rotation
- [1 j 1-j] is the closest CAZAC sequence to extended 11n phase rotation of [1 j 1 j]
- [1 j 1 -j] has no visible backward compatibility issue compared with [1 j 1 j]
- Similar to 802.11n, we propose that this phase rotation be applied to all the symbols in the 802.11ac Mixed Mode Packet

References

- [1] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification. Amendment 5: Enhancements for Higher Throughput, IEEE Std. 802.11n, 2009.
- [2] doc.: IEEE 802.11-09/0847r1. IEEE802.11ac Preamble with Legacy 802.11a/n Backward Compatibility