Comment Resolution related to 4x4 MIMO Practicality (CID 69)

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Authors:

Name	Company	Address	Phone	email
Gabriel Villardi	NICT	Yokosuka, Japan	+81-46-847-5438	gpvillardi@nict.go.jp
Hiroshi Harada	NICT	Yokosuka, Japan		harada@nict.go.jp

Comment Resolution (CID 69)

ID	Comment	Suggested Remedy
69	Due to the physical size of the antennas in the VHF and UHF TV broadcast bands, the use of 4 x 4 MIMO will very likely be limited.	Consider the added complexity to the proposed standard and the probability of use of such technology in practice.

Proposed Resolution:

We propose to keep 4 x 4 MIMO configuration in the standard.

We agree with the comment that in TVWS, the distances required to yield uncorrelated fading among the elements of the antenna array are bigger than the distances required by other wireless communication systems operating at higher frequencies. We however think that 4 x 4 MIMO in TVWS is not unpractical therefore not having limited usability. The reasons for the aforementioned judgment is as follows:

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- Consider the wavelength for f = 600MHz;
  - λ = c/f = 0.5 meters
- For highly positioned antennas (e.g., base-stations, higher relays)
  - Antenna separation of 10 λ to achieve uncorrelated fading [1], [2]
  - 10 λ = 5 meters
- For antennas with comparable height as the local scatters (terminals, lower relay stations)
  - Antenna separation of 0.5 λ to achieve uncorrelated fading [1],[2].
  - 0.5 λ = 0.25 meters

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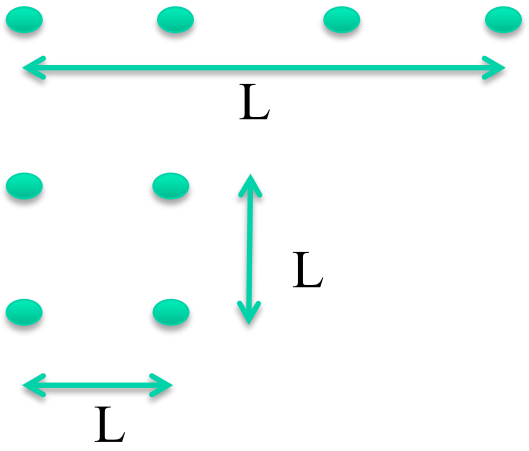
- Several antenna array configurations exist
  - Uniform Linear Array (ULA)
  - Uniform Circular Array (UCA)
  - Uniform Rectangular Array (URA)
  - Uniform Cubic Array (UCuA)
- 4x4 ULA (10 λ BS, High relay)
  - L =15 meters
- 4x4 URA (10 λ BS, High relay)
  - L = 5 meters



- As stated in [1], 4 λ (2 meters) is however capable of achieving 80% of the throughput as compared to 10 λ separation.

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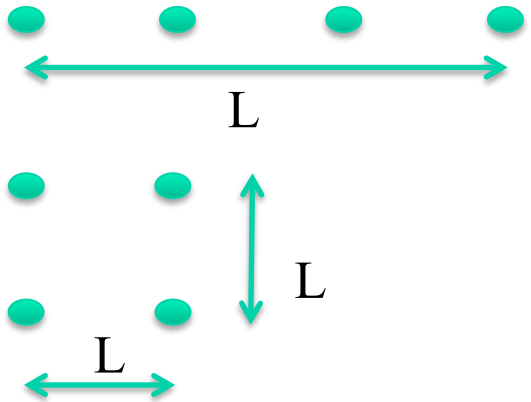
- 4x4 ULA (4 λ BS, High relay)
  - L = 6 meters
- 4x4 URA (4 λ BS, High relay)
  - L = 2 meters



- Despite having a large array, URA of 5 meters (and even ULA of 15 meters) can be practical if one considers that both base stations and relay stations do not necessarily have antennas fixed to it, i.e., antennas can be spread each to different corners of a building roof-top.
- In the case 4 λ is utilized with the cost of 20% throughput reduction, we believe that practicality concerns nearly disappears

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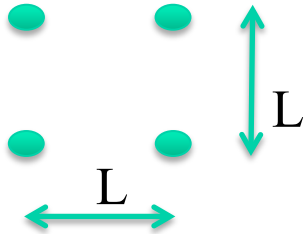
- 4x4 ULA (Terminals, Low relay stations)
  - L =0.75 meter
- 4x4 URA (Terminals, Low relay stations)
  - L = 0.25 meters



For the case of low height antennas, the array length for 4 antennas is obviously practical.

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- ULA and URA do have different throughput
  - $ULA_{throughput} > URA_{throughput}$
- As shown in [3], URA still provided significant spectral efficiency improvement (throughput) as compared to the SISO system. Therefore being also a useful means to realize 4x4 MIMO in TVWS.
- Additionally, [4] develops a compact MIMO antenna by using polarization discrimination, which would further reduce the distance requirements given in this presentation.

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- LTE Band 13 (700MHz) does utilizes 2x2 MIMO [5], [6], which proves the feasibility of having multiple antennas at both the base station and the end user devices in near TVWS bands
  - Remind that the antenna separation requirement for two antennas is the same as the required separation between each antenna of a URA arrangement.
- In fact, the study published in [7] conducted measurements on a 2x2 MIMO in 700MHz. They developed 2 smartphones of 73mm x 150mm (3x6 inches) and 65mm x 115 mm (2.5x4.5 inches), respectively. The throughput performance of both was comparable to the throughput of a ideal reference device not constrained in size.

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- After contacting the author of CID 69 we have agreed to introduce the following the passage to the appropriate MIMO section:

"The MIMO technique described hereafter is more appropriate for the link between base station-relay stations existent in the wireless network backbone of a IEEE 802.22b based system. On the other hand, implementing MIMO on the links between base station-CPEs and relay stations-CPEs is technically more challenging. This is due to the fact that the lower operating frequencies inherent to the TVWS bands require antennas with bigger physical sizes than the ones required by existing wireless communication systems operating at higher parts of the frequency spectrum."

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References

[1] D. Chizhik, F. Rashid-Farrokhi, J. Ling, A. Lozano, "Effect of antenna separation on the capacity of BLAST in correlated channels," IEEE Communications Letters, Vol. 4, No. 11, November 2000.

[2] Multi-Antenna Transceiver Techniques for 3G and Beyond", Ari Hottinen, Olav Tirkkonen and Risto Vichman, John Willey and Sons, 2004.

[3] A.A. Abouda, H.M. El-Sallabi and S.G. Haggman, "Effect of Antenna Array Geometry and ULA Azimuthal Orientation on MIMO Channel Properties in Urban City Street Grid", Progress in Electromagnetic Research, PIER 64, 257-278, 2006.

[4] J.B. Andersen and B.N. Getu, "The MIMO Cube – a Compact MIMO Antenna", Proc. Of IEEE Wireless personal Multimedia Commun. Vol. 1, 112-114, 2002.

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References

[5] 4G LTE White Paper, “The Verizon Wireless 4G LTE Network: Transforming Business with Next-Generation Technology”

[6] http://www.marketwatch.com/story/ejl-wireless-research-adds-the-alcatel-lucent-lte-trdu-700mhz-b13-radio-unit-to-its-design-analysis-infrastructure-dna-i-series-of-teardown-reports-2013-12-30

[7] Bo Hagerman, Karl Werner, “MIMO Performance at 700MHz: Field Trials of LTE with Handheld UE”.