Solving the polarization problem in ALMA-VLBI observations

Towards high-fidelity polarimetry with the EHT

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Nordic Node of the European ALMA Regional Center

National Facility for Radio Astronomy

Onsala Space Observatory (Sweden)

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The ALMA Phasing Project (APP) Team

(Incomplete list)

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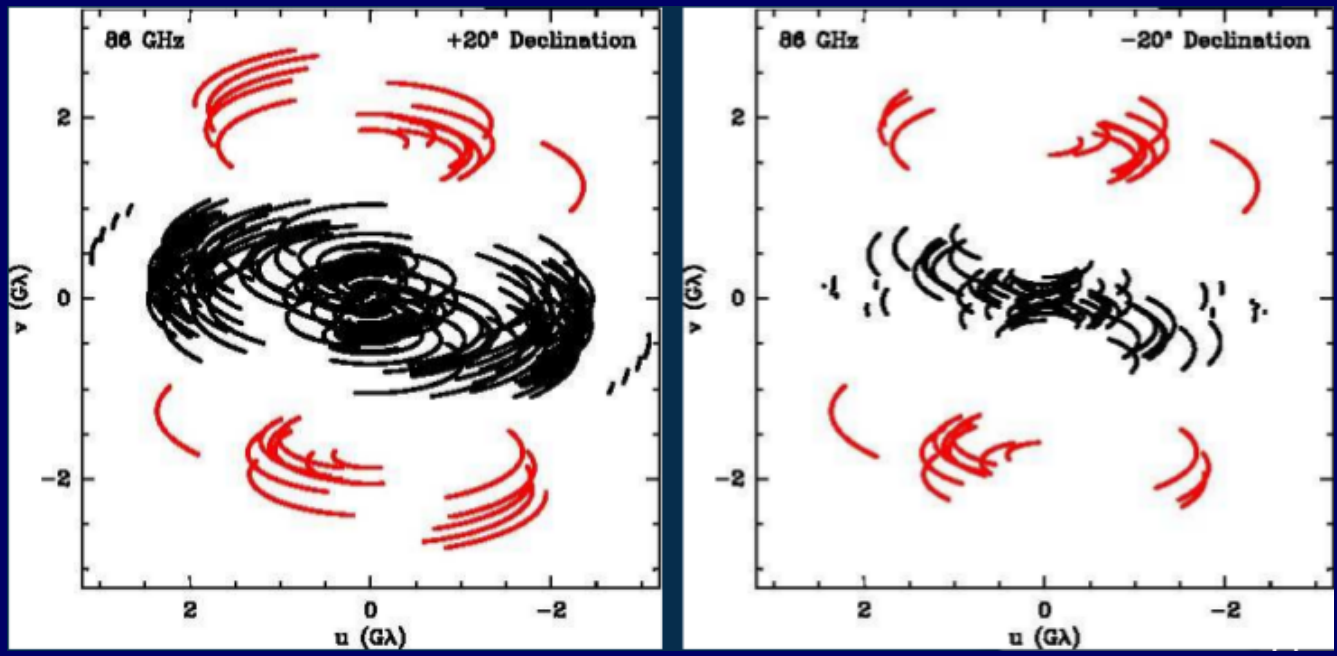
- NRAO
  - Rich Lacasse, Ray Escoffier, Joseph Greenberg, Bill Shillue, Bob Treacy, Rafael Hiriart, Matias Mora, ...
- MPIfR
  - Walter Alef, Alan Roy, Helge Rottman, ...
- Onsala
  - Iván Martí-Vidal, Tobia Carozzi, Michael Lindqvist, ...

..., Alan Baudry (ESO), Mareki Honma (NAOJ), Tomoaki Oyama (NAOJ), Makoto Inoue (ASIAA), Nicolas Pradel (ASIAA), Robert Lucas (UJF), Neil Nagar (UDEC), Alejandro Sáez (ALMA), Bernhard López (ALMA) Jonathan Weintroub (CfA), ...

The ALMA Phasing Project

- Use the whole ALMA as one single (VLBI) station.
- Large increase in sensitivity (and image fidelity) for mm-VLBI.
- Will reach a few 10s of μas resolution!



UV Coverage of Global VLBI at 3mm (ALMA in red)

See Fish et al. (arXiv:1309.3519)

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- Will improve sensitivity by a large factor.

	PdB	CARMA	SMTO	APEX	ALMA
P. Veleta	0.063	0.076	0.201	0.169	0.024
PdB	-	0.058	0.153	0.129	0.019
CARMA	-	-	0.185	0.155	0.022
SMTO	-	-	-	0.413	0.059
APEX	-	-	-	-	0.050

Baseline sensitivity (Jy) at 1mm for 10s int. time

See Fish et al. (arXiv:1309.3519)

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- Different frequency sampling in digitizer (2^n MHz sub-bands for VLBI; 62.5 MHz sub-bands for ALMA).

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- Polarization compatibility (ALMA registers in X/Y base; VLBI stations register in RCP/LCP base).

ALMA polarization for VLBI

Roy et al. (2013). *APP polarization White Paper*

Final strategy is

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- Convert to pure circular basis (RR, LL, RL, LR) **after correlation**.

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The main advantages are

- Minimum hardware implementation.
- Flexibility for post-processing.
- Easy adaptability for future X/Y-based stations.

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- $$K^{i}_{+} = \begin{pmatrix} B^{i}_{x} & 0 \\ 0 & B^{i}_{y} \end{pmatrix} \times \begin{pmatrix} 1 & 0 \\ 0 & e^{j\alpha_i} \end{pmatrix} \times \begin{pmatrix} 1 & D^{i}_{x} \\ D^{i}_{y} & 1 \end{pmatrix}$$

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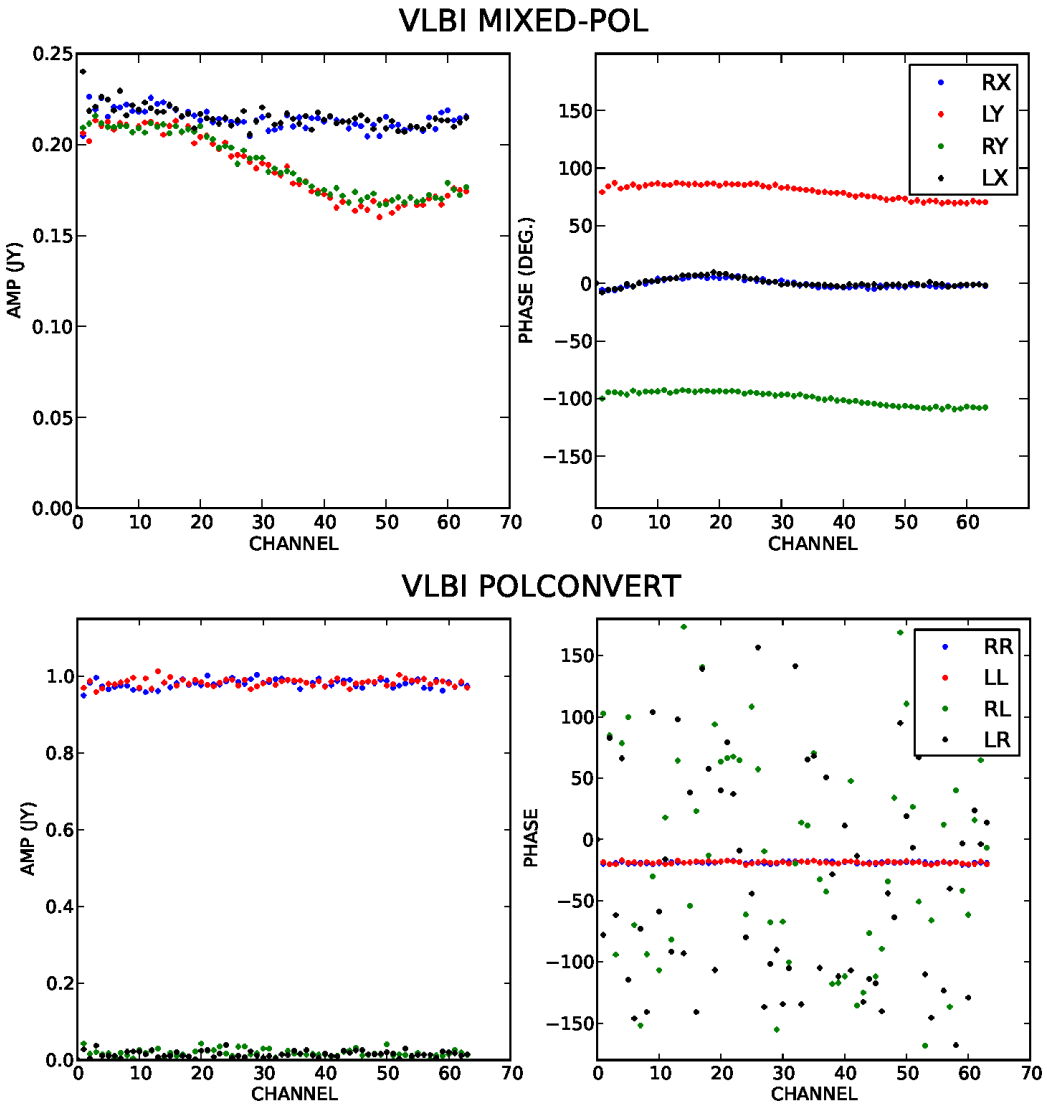
- Conversion fully implemented in our software, PolConvert.

Simulation results. Unpolarized source



- 10 ALMA antennas (XY basis).
- Different X/Y gains (BP, G, K, and D) in each ALMA antenna.
- 1 VLBI station (RL basis).
- Realistic simulation (thermal noise, signal quantization, etc.)
- Simulation output:
  - ALMA cross-products (MS).
  - VLBI fringe (SWIN).

Tests with real data I: Onsala-Effelsberg at 86 GHz

Thanks to COST Action MP1104 for travel support to MPIfR!

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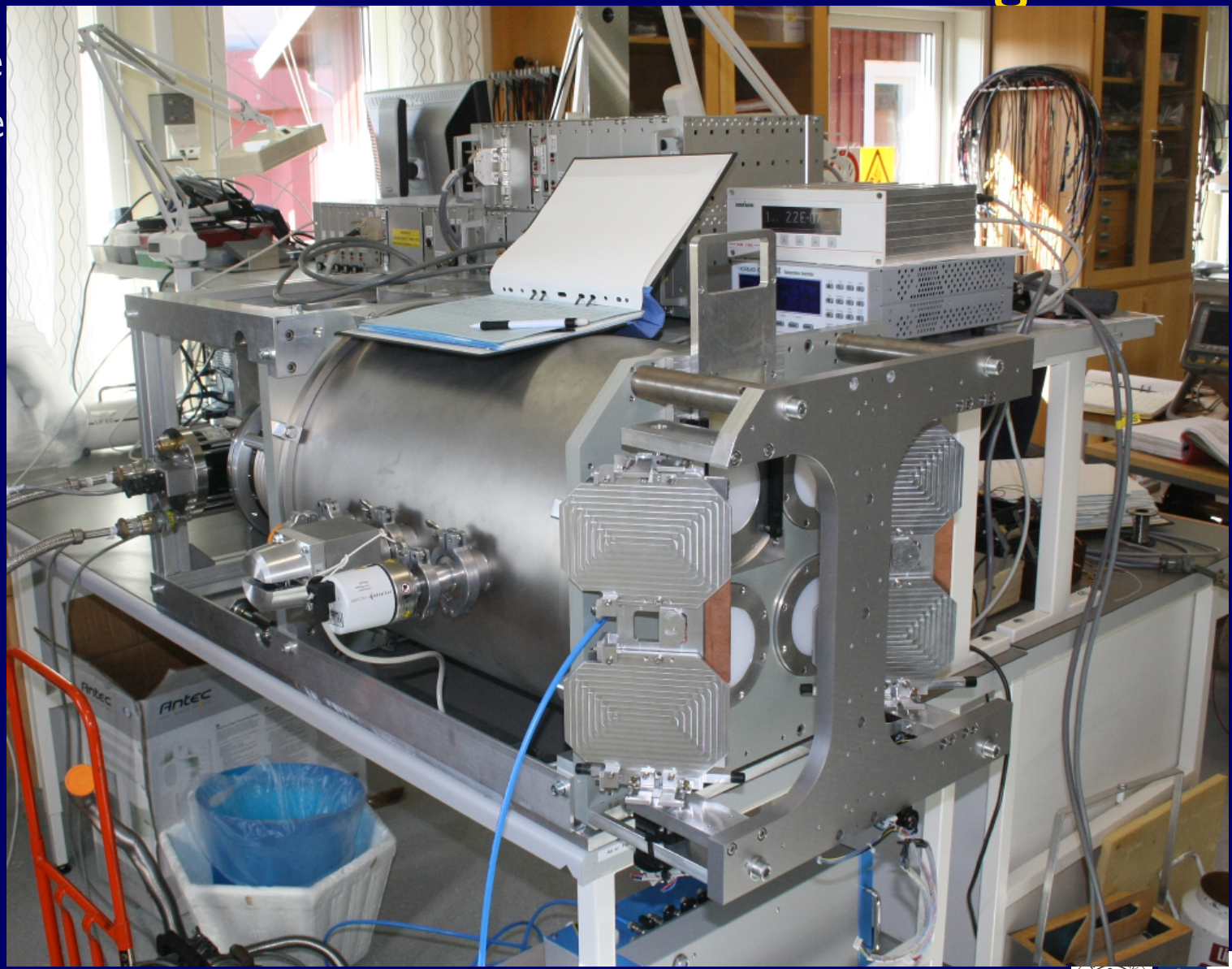

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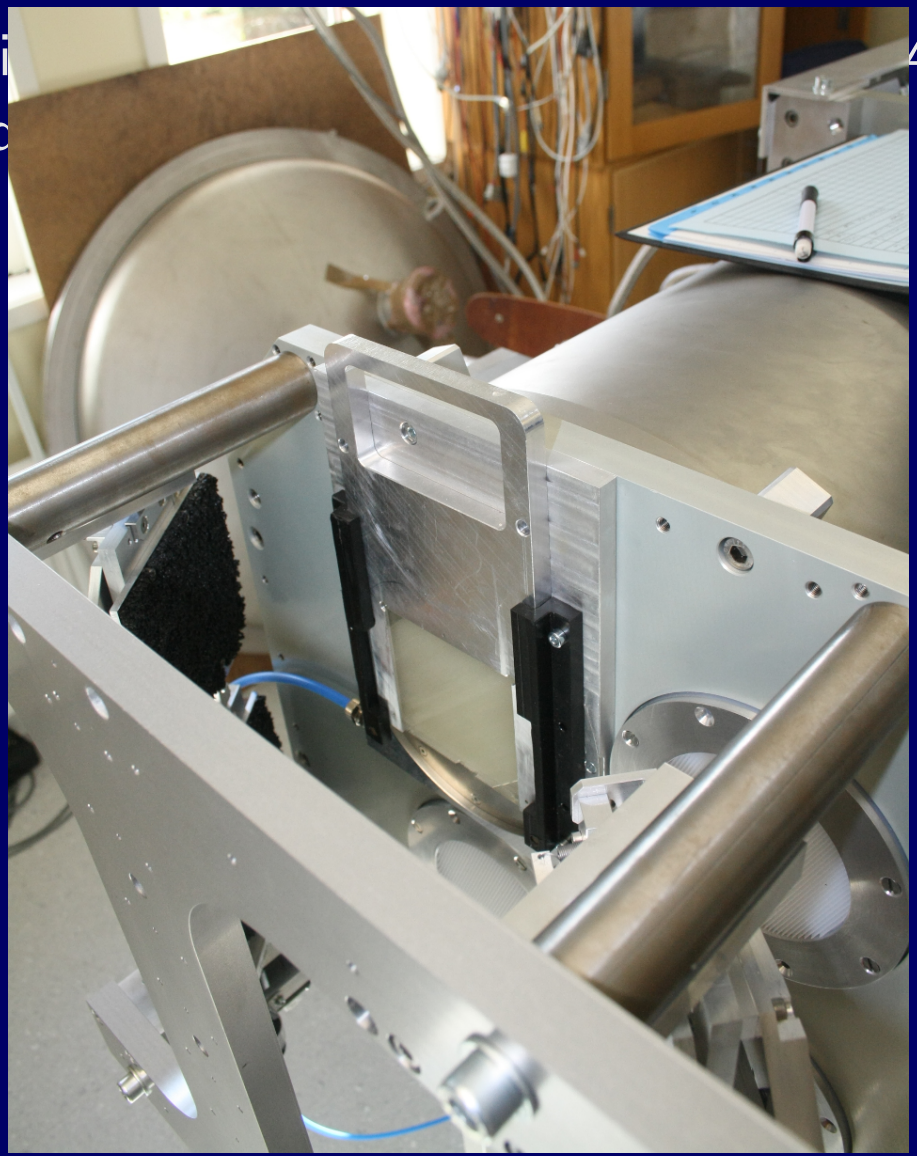

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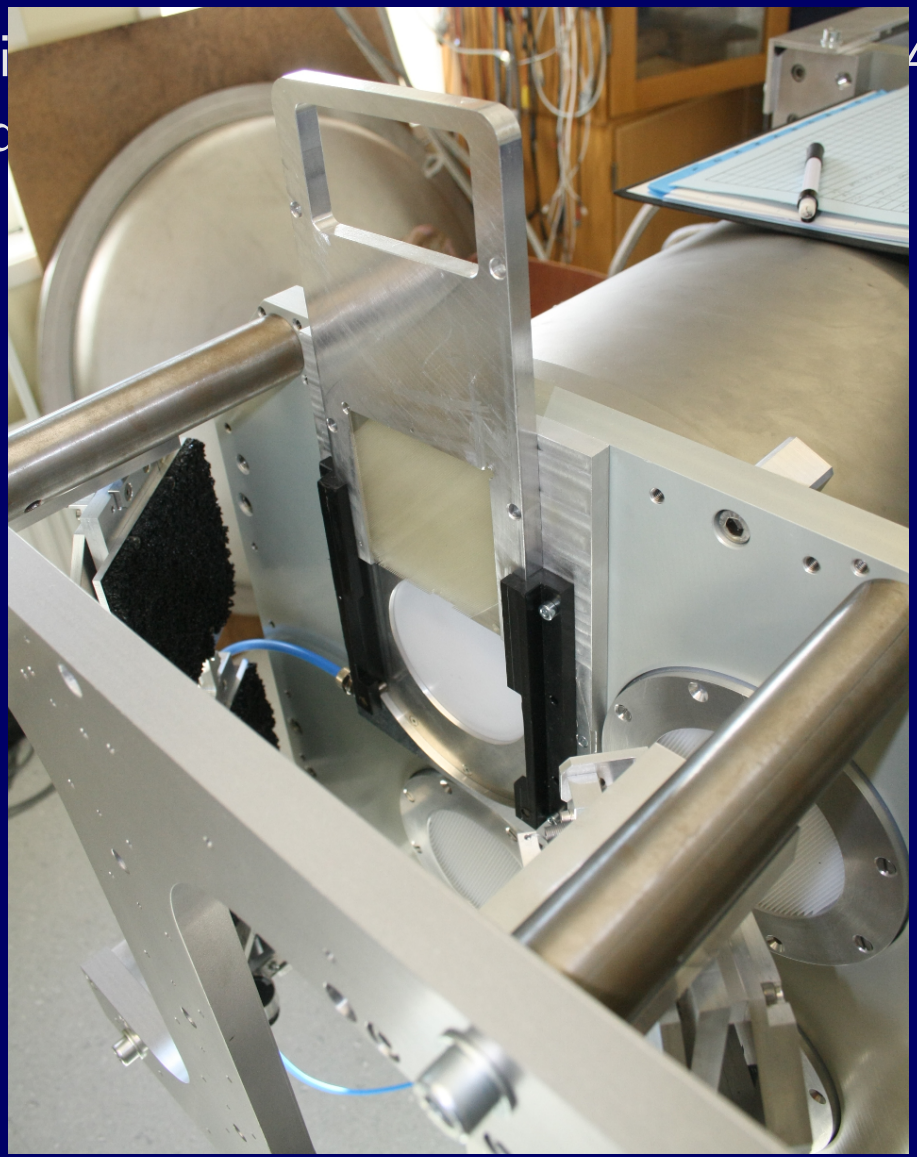

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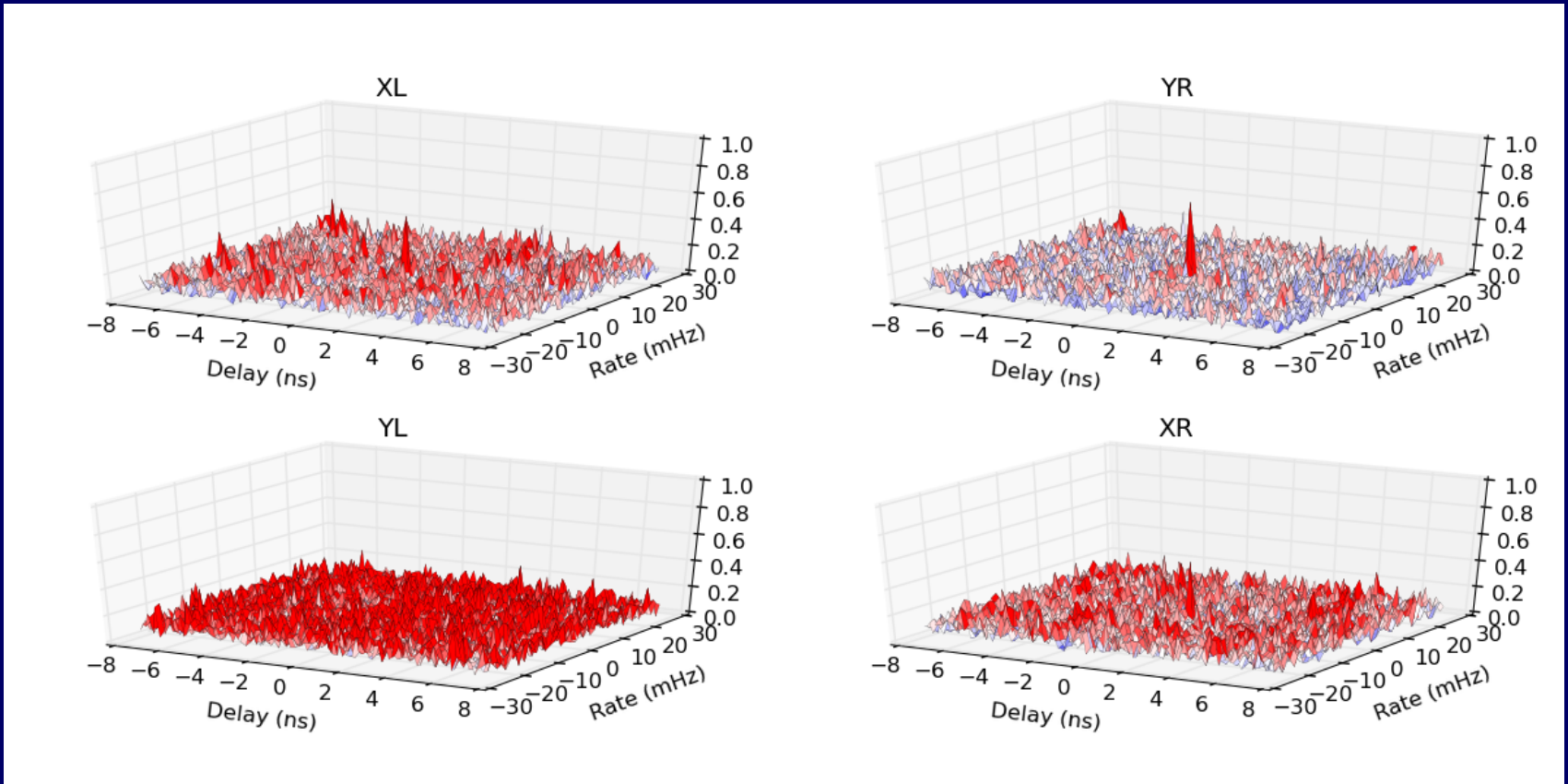
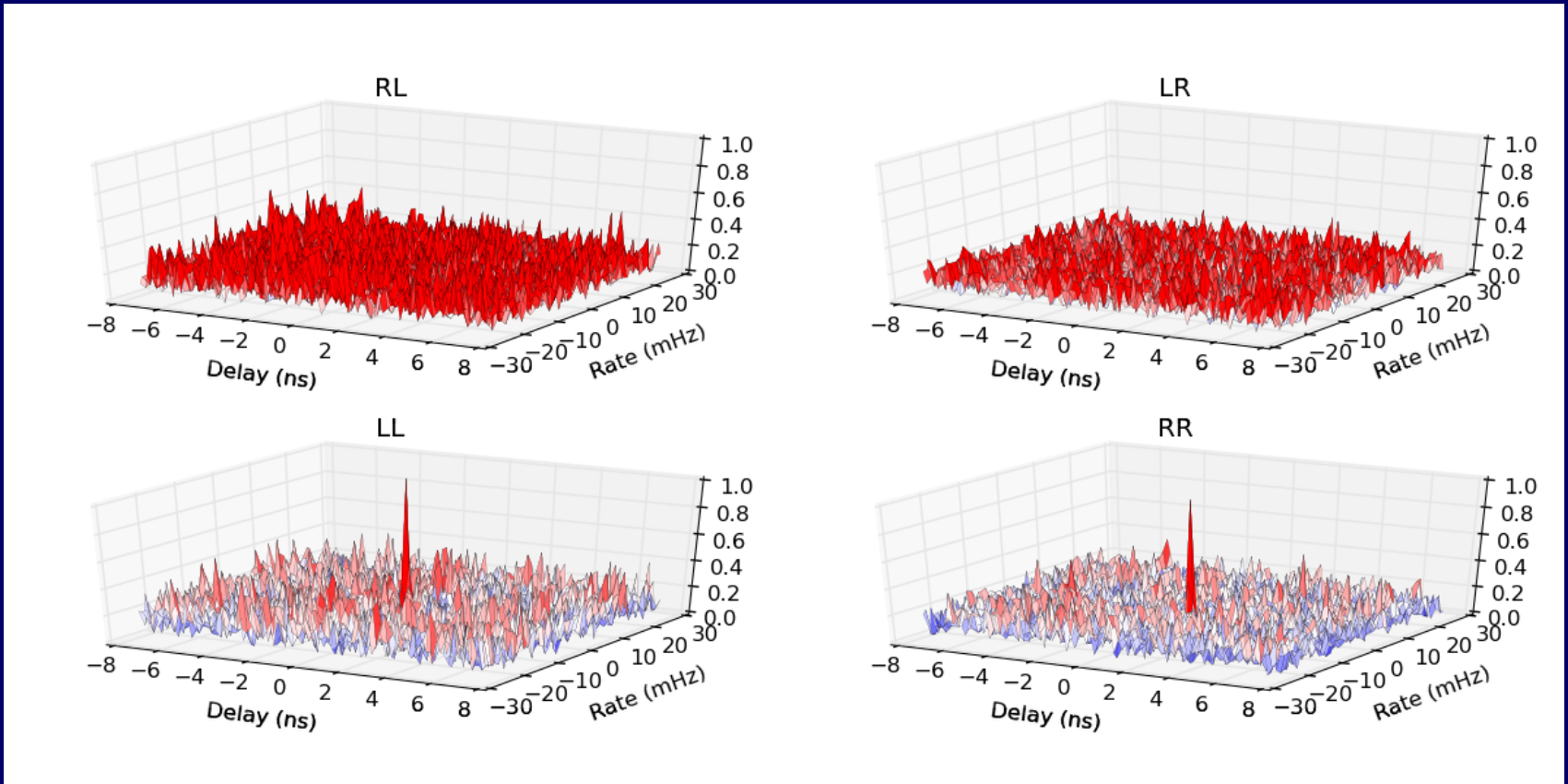
On-Eb mixed-polarization fringes



On-Eb final pol-converted fringes



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THANKS!

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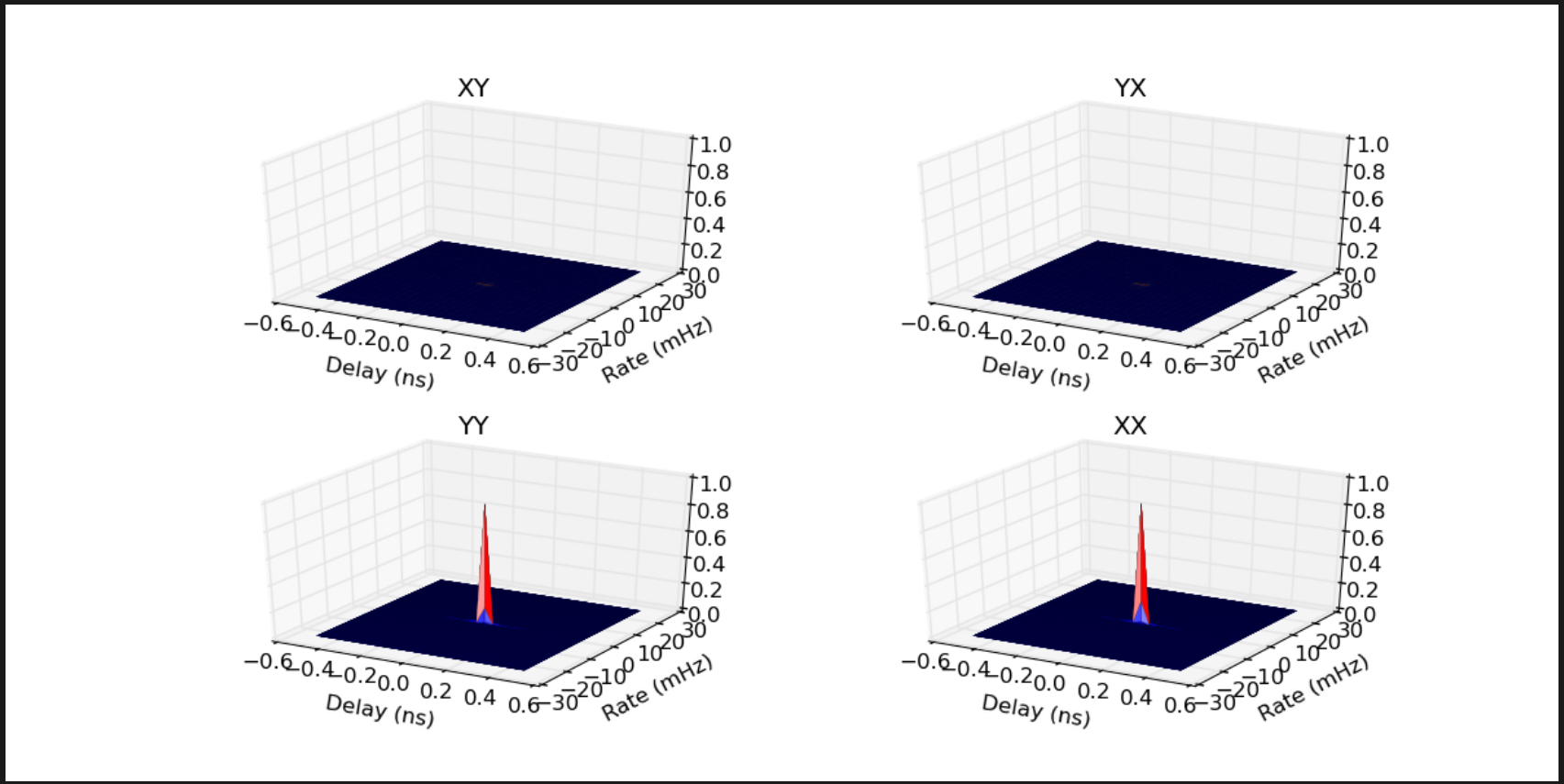
- PolConvert was applied *twice* to convert visibilities to pure circular basis.

First Phased-ALMA fringes!



Phased vs. Antenna 1 - Linear

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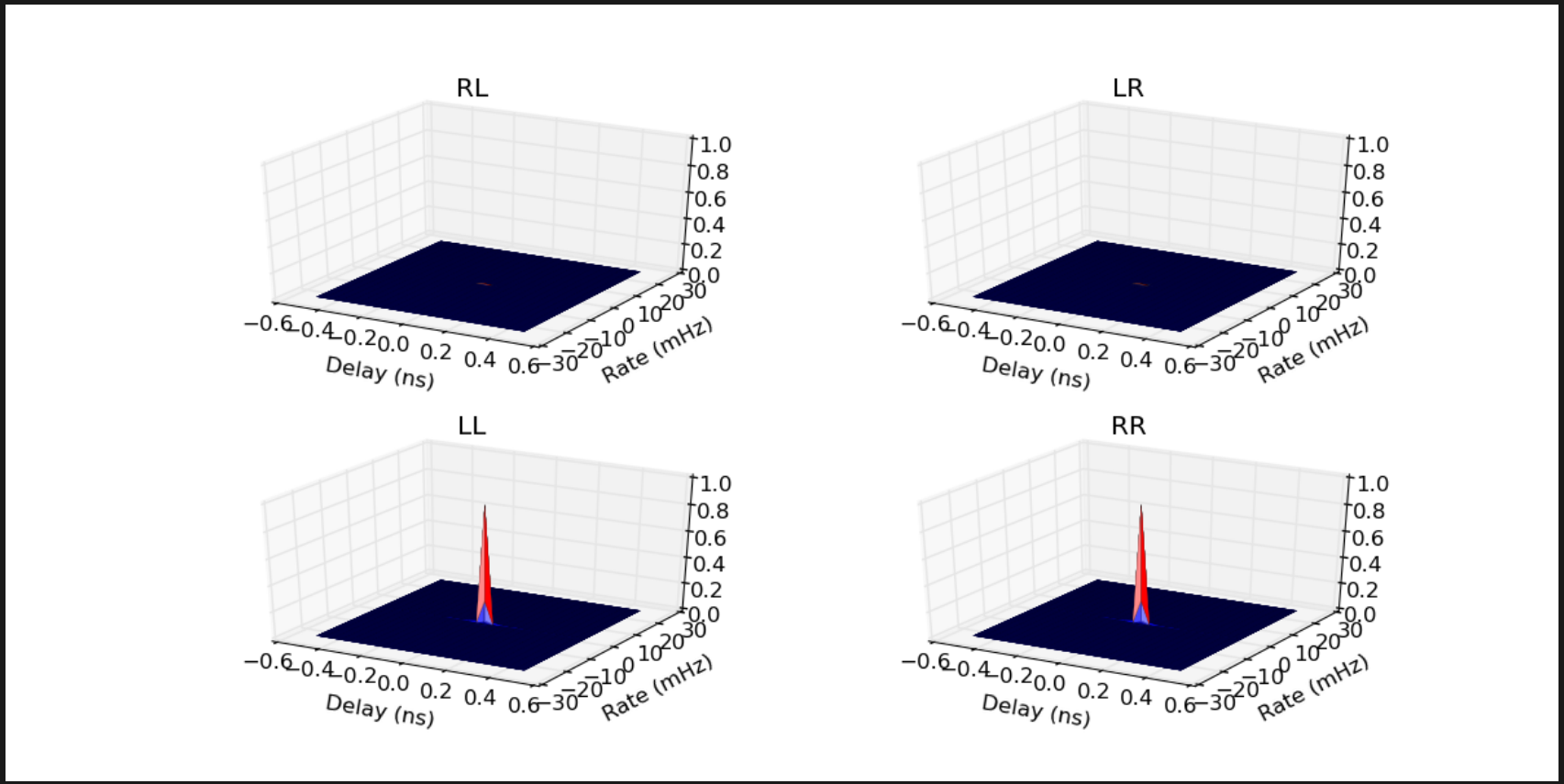

Phased vs. Antenna 1 - Circular

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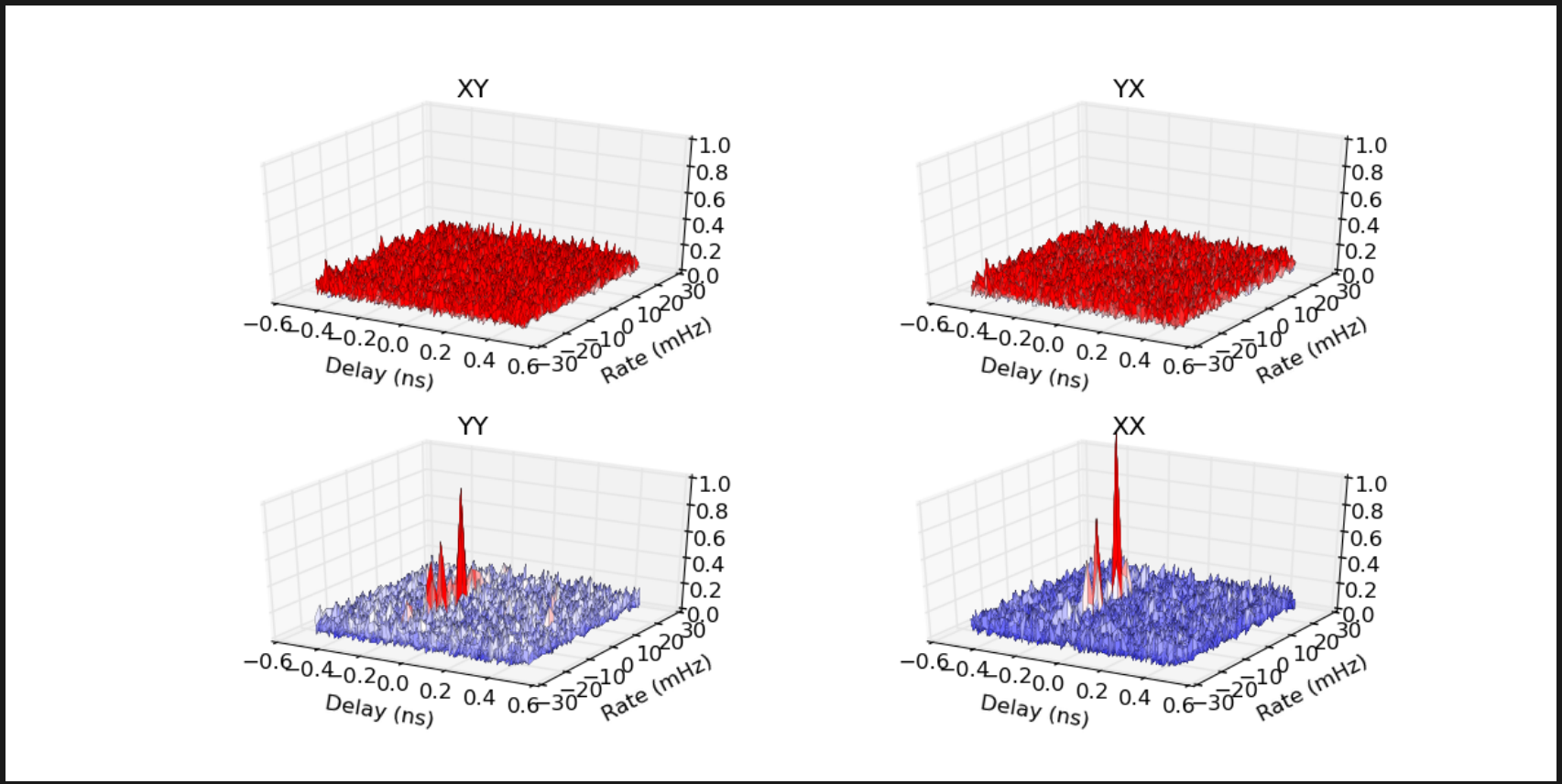

Antenna 1 vs. Antenna 2 - Linear

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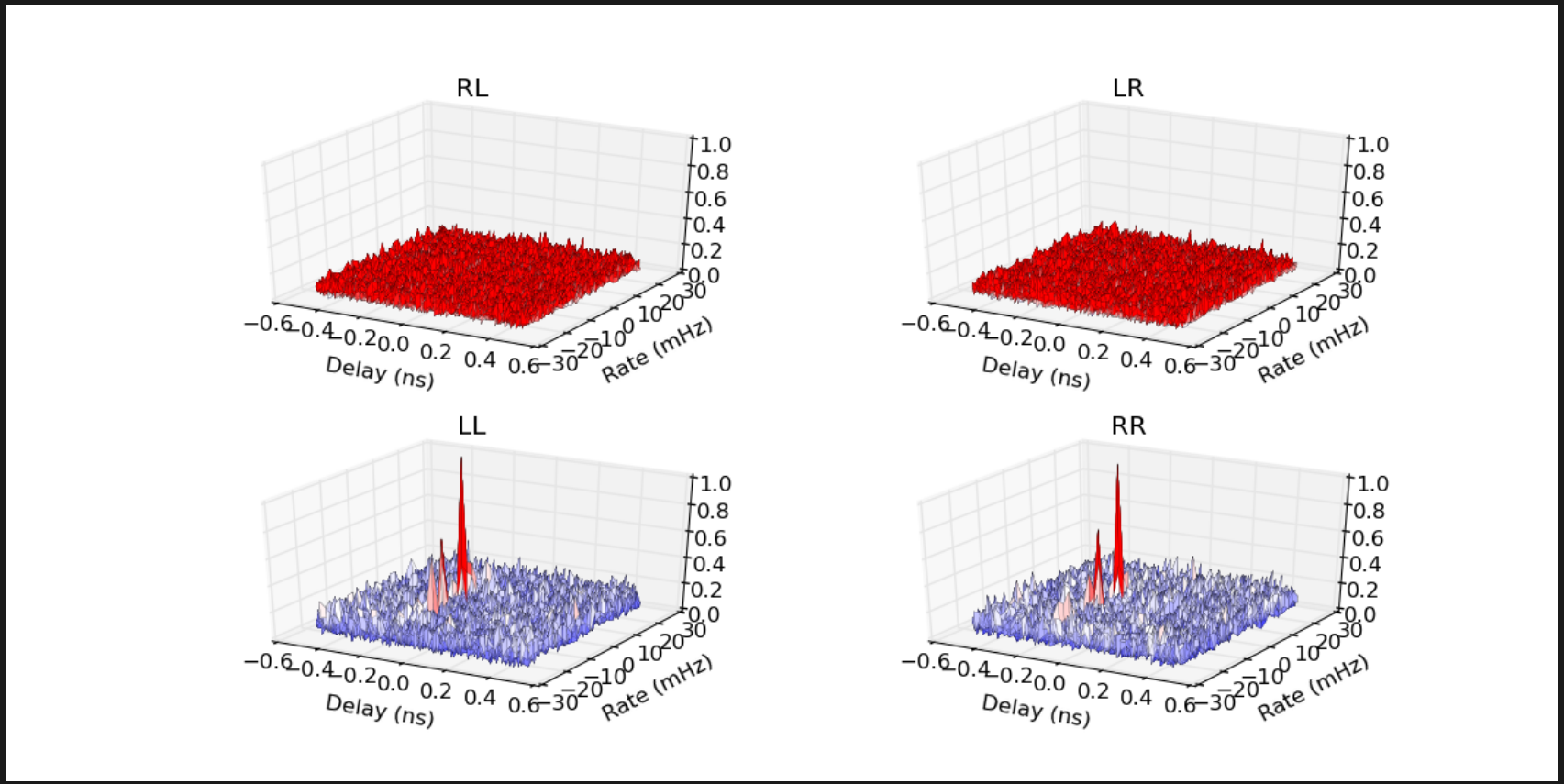

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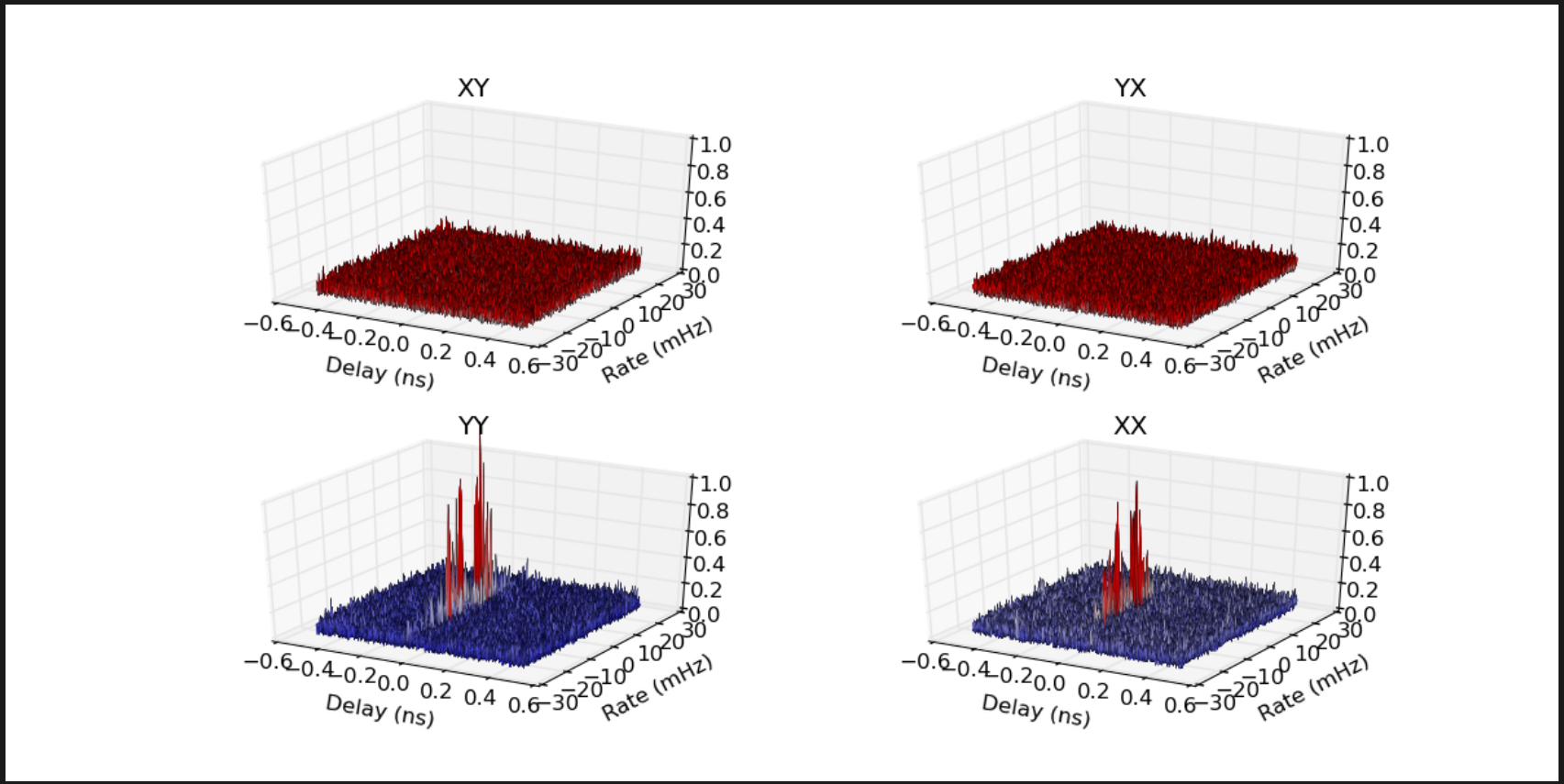

Antenna 1 vs. Antenna 3 - Linear

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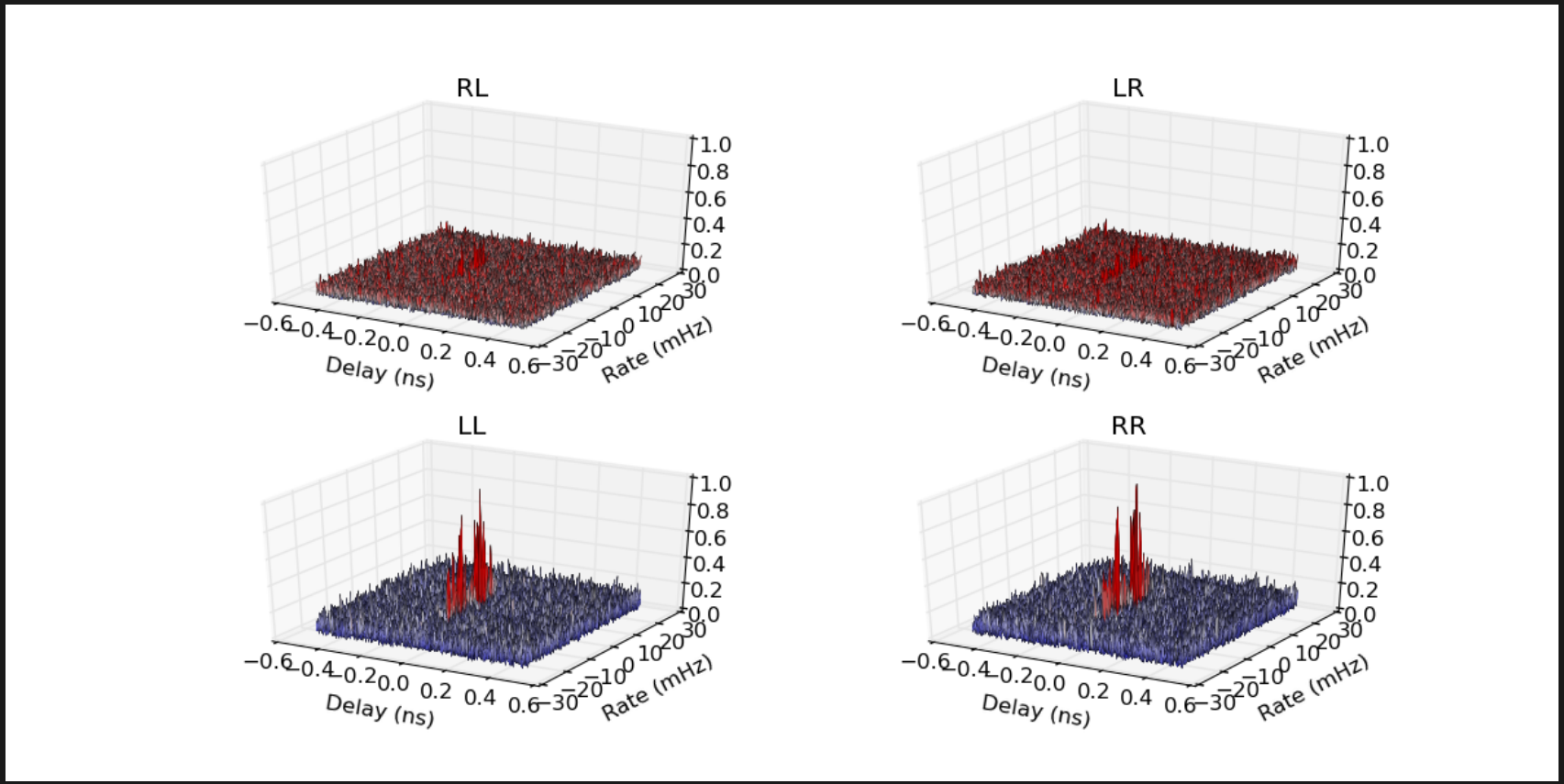

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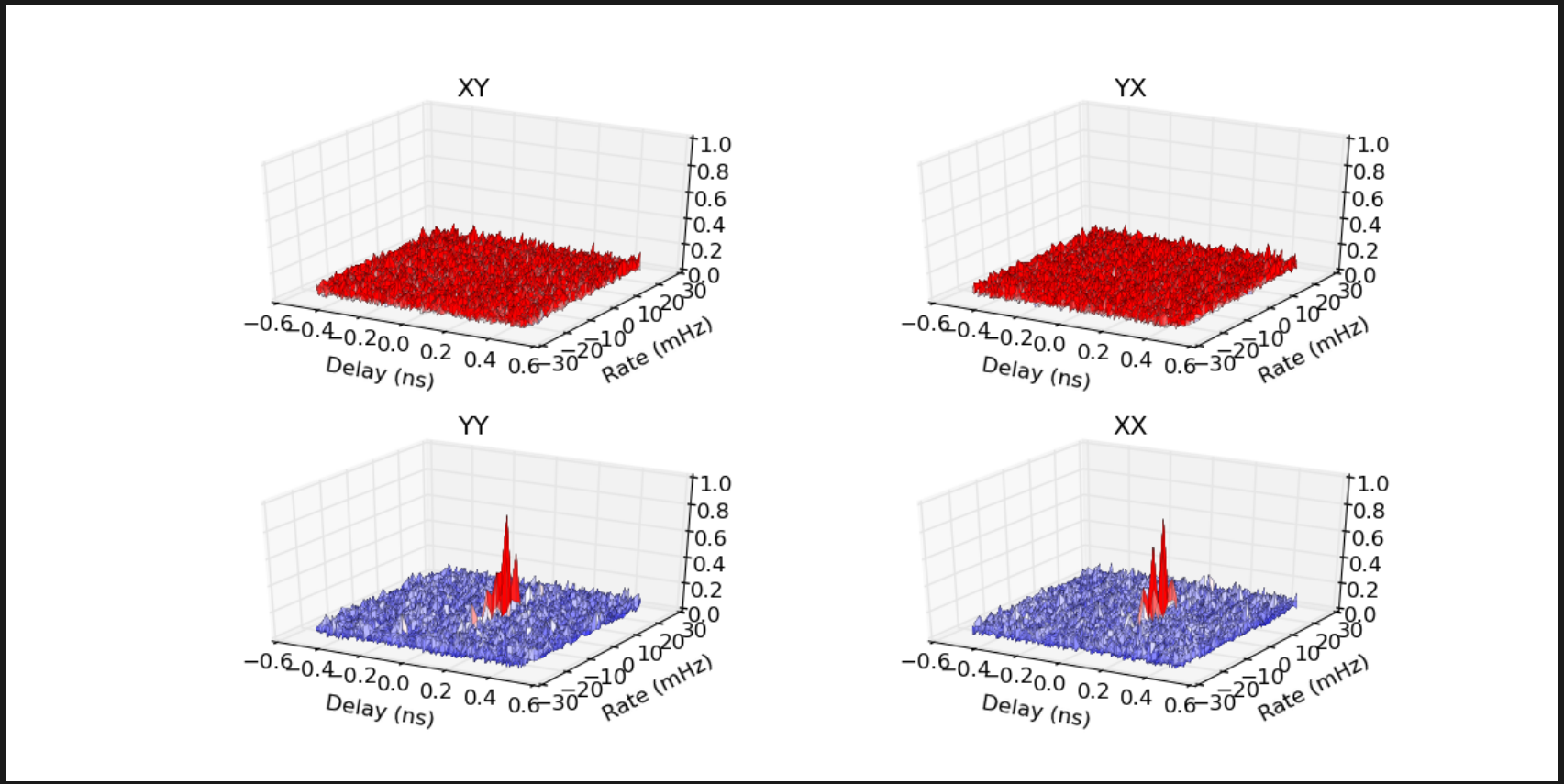

Antenna 2 vs. Antenna 3 - Linear

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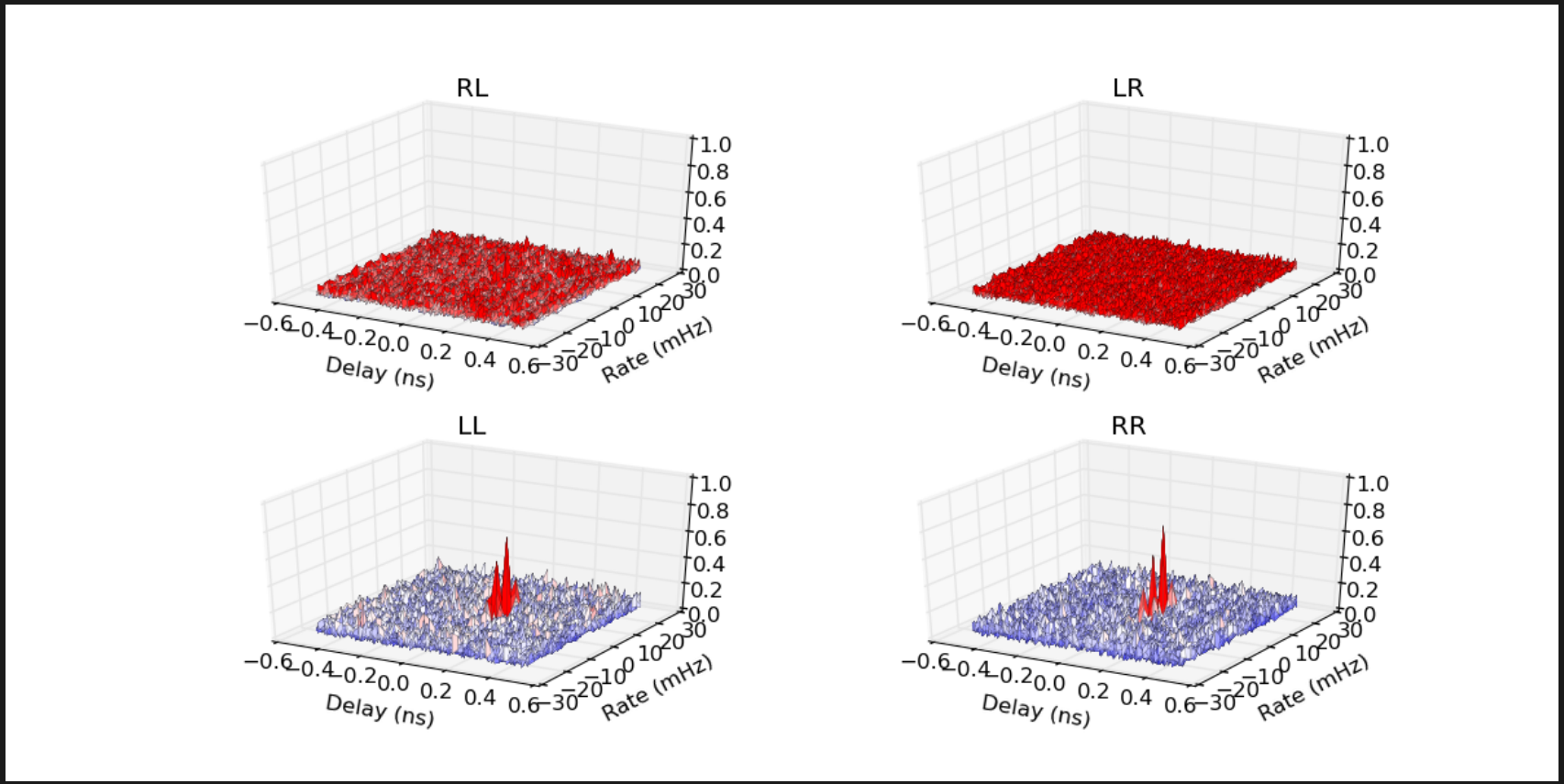
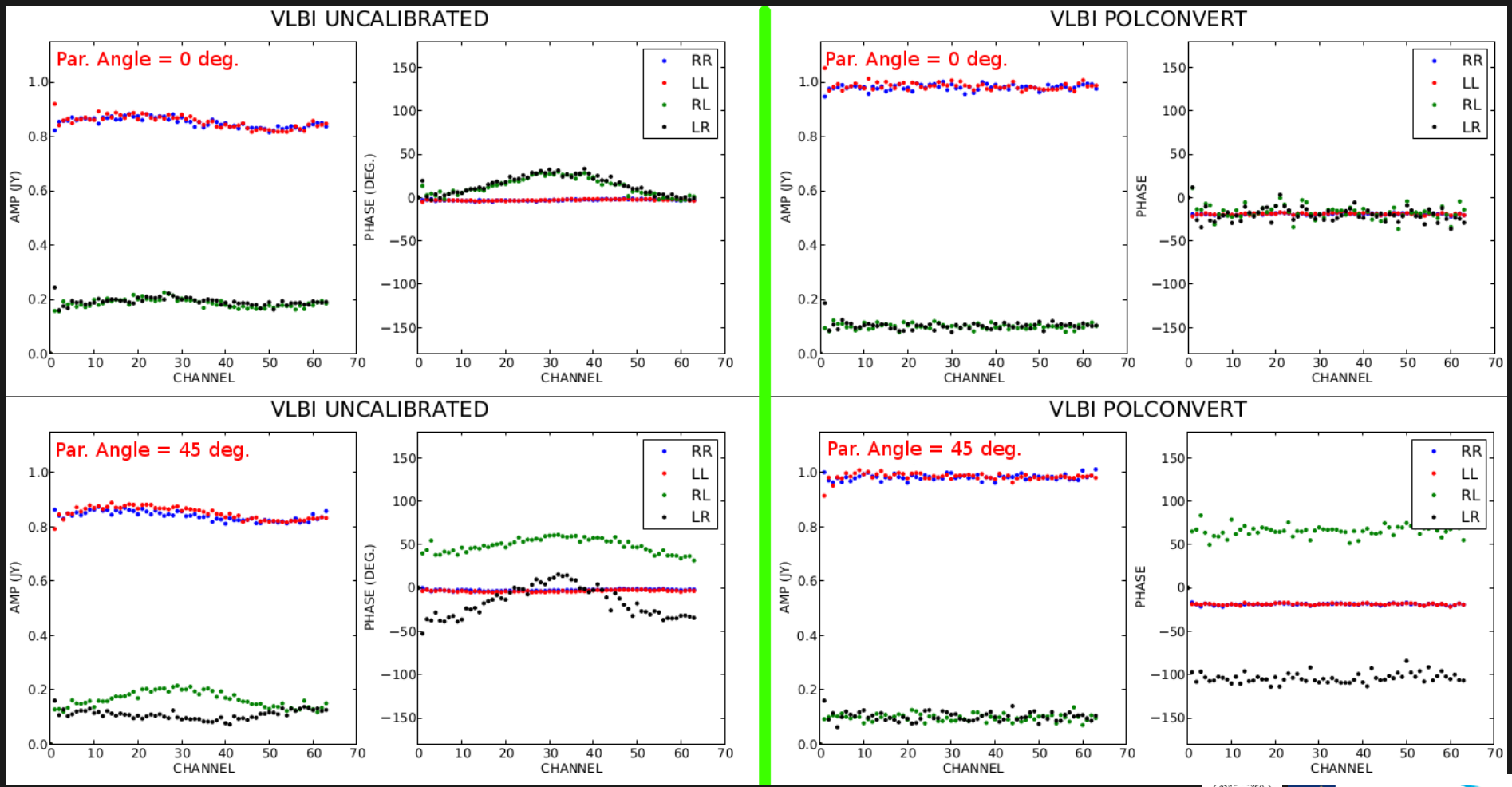


Antenna 2 vs. Antenna 3 - Circular

Simulation results II. Linearly polarized source

Stokes parameters (Jy): $I = 1.0$, $Q = 0.1$, $U = 0.0$, $V = 0.0$



On-Eb quick pol-converted fringes