RAPID for Dual-Polarized Interferometry of Lightning

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Lightning as a radio source
Lightning as a radio source
Lightning as a radio source
Lightning as a radio source
Lightning as a radio source
Lightning as a polarized radio source

RAPID array configuration
RAPID array configuration

<table>
<thead>
<tr>
<th>Antennas:</th>
<th>(three) Long Wavelength Array (LWA) antennas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digitizers:</td>
<td>(three) Ettus X300 radio at 200 Msps IQ</td>
</tr>
<tr>
<td>Resolution:</td>
<td>14 bits</td>
</tr>
<tr>
<td>Center frequency:</td>
<td>45 MHz</td>
</tr>
<tr>
<td>Bandwidth:</td>
<td>50 MHz (10-70 MHz)</td>
</tr>
<tr>
<td>Baselines:</td>
<td>335 m, 469 m, and 606 m</td>
</tr>
<tr>
<td>Dual-polarization:</td>
<td></td>
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</tbody>
</table>
Interferometry – concept

\[ \cos \alpha = \frac{c \tau_d}{d} = \left( \frac{\Delta \phi}{2\pi} \right) \frac{\lambda}{d} \]
Interferometry – VHF waveforms
Interferometry – VHF waveforms

Window 12, vhf_A times series

digital amplitude

0 2 4 6 8 10 12

Window 12, vhf_B times series

time (µs) +3.588788844e10

digital amplitude

0 2 4 6 8 10 12

Window 12, vhf_C times series

time (µs) +3.588788844e10

digital amplitude

0 2 4 6 8 10 12
Interferometry – cross correlations

- xcorr of vhf_A and vhf_B in Window 12
- xcorr of vhf_A and vhf_C in Window 12
- xcorr of vhf_B and vhf_C in Window 12

(physically possible) time delays (s)
Interferometry – cross correlations

Time delay where xcorr is max
Interferometry – cosine plane projection

Time delay where $xcorr$ between signals A and B is max
Interferometry – cosine plane projection

Time delay where xcorr between signals A and C is max

Time delay where xcorr between signals A and B is max

orientation of baseline AB

orientation of baseline AC

east

north
Interferometry – ideal point source

Image by projecting xcorrs into cosine plane

idx=0, delt=0.0000us, #samps/frame=2000,
#samps shift btwn frames=1000

North
South
West
East
Interferometry – ideal point source
Interferometry – real source

Image by projecting xcorrs into cosine plane

idx=21300, delt=0.0000us, #samps/frame=300, #samps shift btwn frames=150
Interferometry – real source

Image by projecting xcorrs into cosine plane

idx=21450, delt=1.0714us, #samps/frame=300, #samps shift btwn frames=150
Interferometry – real source

Image by projecting xcorrs into cosine plane

idx = 21600, delt = 2.1429us,
#samps/frame = 300, #samps shift btw frames = 150
Interferometry – real source

Image by projecting xcorrs into cosine plane

idx=21750, delt=3.2143us, #samps/frame=300, #samps shift btwn frames=150
Interferometry – flash 1
Interferometry – flash 1
Interferometry – flash 2
Interferometry – flash 2
Interferometry + Polarization

\[ I = \langle E_{NS}^2 \rangle + \langle E_{EW}^2 \rangle \]
\[ Q = \langle E_{NS}^2 \rangle - \langle E_{EW}^2 \rangle \]
\[ U = 2\langle E_{NS} E_{EW} \cdot \cos(\Delta \phi_{NS} - \Delta \phi_{EW}) \rangle \]
\[ V = 2\langle E_{NS} E_{EW} \cdot \sin(\Delta \phi_{NS} - \Delta \phi_{EW}) \rangle \]

\[ d = \frac{\sqrt{Q^2 + U^2 + V^2}}{I} \]