New Surface Measurement System

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Atacama Large Millimeter/submillimeter Array
Karl G. Jansky Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array
Surface Measurement System

• Current OOF measurement takes ~ 30 – 40 minutes
• Needs for Q-band (~ 40 GHz) and above
• High overhead (night-time)
• Not practical (day-time)

• Need a faster alternative!

• “Metrologies at Radio Astronomy Antennas”
  – ERATec 2014, Gothenburg, Sweden

• “Aiming at self-calibration of terrestrial laser scanners using only one single object and one single scan”
  – “Object” was the Effelsberg radio telescope
Leica ScanStation P40

System Accuracy

<table>
<thead>
<tr>
<th>Accuracy of single measurement</th>
<th>1.2 mm + 10 ppm over full range</th>
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</thead>
<tbody>
<tr>
<td>Range accuracy</td>
<td>3 mm at 50 m, 6 mm at 100 m</td>
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<tr>
<td>Angular accuracy</td>
<td>8° horizontal, 5° vertical</td>
</tr>
<tr>
<td>3D position accuracy</td>
<td>2 mm standard deviation at 50 m</td>
</tr>
<tr>
<td>Target acquisition</td>
<td>Liquid sensor with real-time onboard compensation, selectable on/off, resolution 1”, dynamic range ±5”, accuracy 1.5”</td>
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<tr>
<td>Dual-axis compensator</td>
<td></td>
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</tbody>
</table>

Distance Measurement System

<table>
<thead>
<tr>
<th>Type</th>
<th>Ultra-high speed time-of-flight enhanced by Waveform Digitising (WFD) technology</th>
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</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>1550 nm (invisible) / 658 nm (visible)</td>
</tr>
<tr>
<td>Laser class</td>
<td>1 (in accordance with IEC 60825:2014)</td>
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<tr>
<td>Beam divergence</td>
<td>&lt; 0.23 mrad (FWHM, full angle)</td>
</tr>
<tr>
<td>Beam diameter at front window</td>
<td>≤ 3.5 mm (FWHM)</td>
</tr>
<tr>
<td>Range and reflectivity</td>
<td>Minimum range 0.4 m</td>
</tr>
<tr>
<td></td>
<td>Maximum range at reflectivity (120 m, 180 m, 270 m)</td>
</tr>
<tr>
<td>Scan rate</td>
<td>Up to 1000'000 points per second</td>
</tr>
<tr>
<td>Range noise</td>
<td>0.4 mm rms at 10 m</td>
</tr>
<tr>
<td></td>
<td>0.5 mm rms at 50 m</td>
</tr>
<tr>
<td>Field-of-view</td>
<td>Horizontal 360°, Vertical 270°</td>
</tr>
<tr>
<td>Data storage capacity</td>
<td>250 GB internal solid-state drive (SSD) or external USB device</td>
</tr>
<tr>
<td>Communications/Data transfer</td>
<td>Gigabit Ethernet, integrated Wireless LAN or USB 2.0 device</td>
</tr>
<tr>
<td>Onboard display</td>
<td>Touchscreen control with stylus, full colour VGA graphic display (640 x 480 pixels)</td>
</tr>
<tr>
<td>Laser plummet</td>
<td>Laser class 1 (IEC 60825:2014)</td>
</tr>
<tr>
<td></td>
<td>Sending accuracy: 1.5 mm at 1.5 m, Laser dot diameter: 2.5 mm at 1.5 m, Selectable ON/OFF</td>
</tr>
</tbody>
</table>

3D accuracy: 6mm @ 100m
Range noise: 0.5mm @ 50m
Data Processing (Fred Schwab)
Sta–14 Model

Sta–16 Model

Sta–14 (blue) and Sta–16 (red) best–fit Zernike coefficients

Zn (microns)

n

Sta–14 Model Minus Sta–16 Model
RMS Differences:
- $|r| < 50\text{m} = 68\mu\text{m}$
- $|r| < 45\text{m} = 48\mu\text{m}$
- $|r| < 40\text{m} = 38\mu\text{m}$

RMS of single a measurement: $\sim 35\mu\text{m}$

RMS of two subsets of the same run $\sim 18\mu\text{m}$

best case OOF holography: $\sim 40\mu\text{m}$
Estimated error budget

- Small-scale errors:
  - panel manufacturing plus gravity error: 127 µm
  - residual actuator error: 80 µm
  - panel corner setting error: 80 µm
  - panel-scale thermal errors: 100 µm
  - subreflector: 75 µm
  - total small-scale error: 80 + 80 + 127 + 100 + 75 = 211 µm

- Large-scale thermal error: 100 µm

- Total error: 211 + 100 = 235 µm

  ~ 200 µm!

- Current OOF overhead ~ 30 m in 2 hr ~ 25%
- Potential Scan overhead ~ 5 m in 2 hr ~ 4%
- Independent of atmospheric opacity
- Daytime observing becomes possible!
Ruze Efficiency

Ruze Efficiency for 350, 235, 200, 190 microns surface rms

- 350 um (day)
- 235 um (night)
- 200 um (potential)
- 190 um (limit)

Frequency (GHz)

85 GHz Ruze Efficiency

115 GHz Ruze Efficiency
Leica ScanStation P40 3D Laser Scanner

$123,915 online

$86,740 with academic discount!
Anyone interested to collaborate?
Thank you!