Jet Propulsion Laboratory
California Institute of Technology

OPALS Downlink Data

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Outline

- OPALS Mission
- Links Description and Data Format
- Downlink Analysis
- Conclusions

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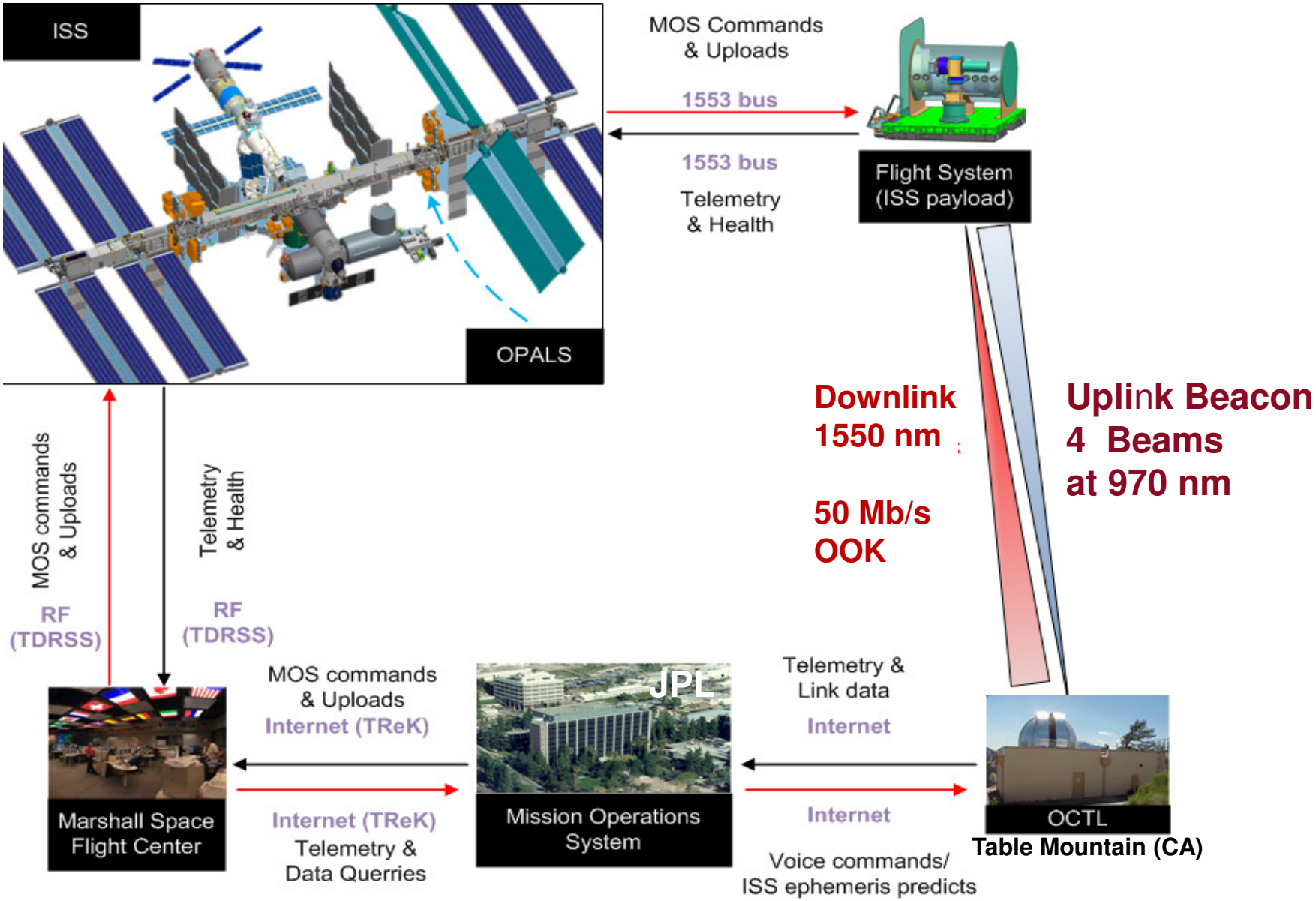
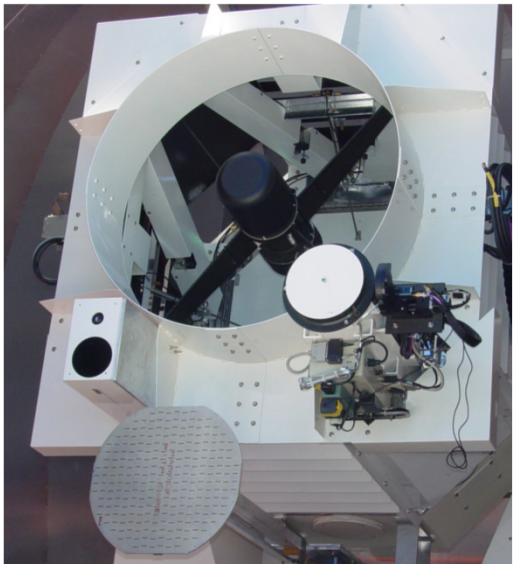
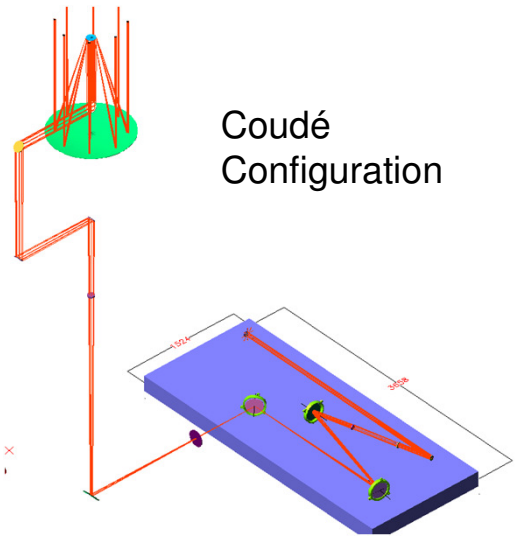
OPALS OVERVIEW

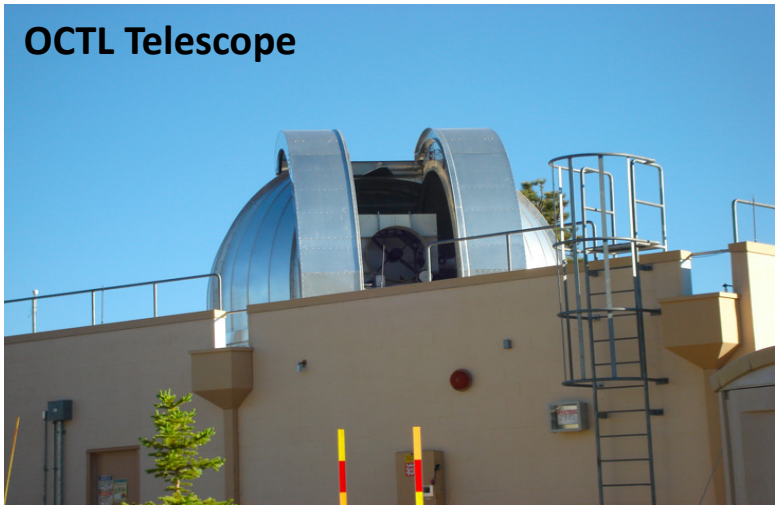


Ground Station at Table Mountain (CA)

- **OCTL telescope 1-m diameter Coudé configuration**
  - 34.4°N Lat; 242.3°E Long; 2300 m a.s.l
  - F/76 w/near diffraction limited field-of-view (FOV) of 500-µrad
  - Tracking rates support LEO-to- deep-space
  - Day & Night operations 7° from Sun
  - T1 line connectivity







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OPALS Links for CCSDS

Pass No.	UTC Start TIME (yyyy:mm:HH:MM:SS)	Local TIME (yyyy:mm:HH:MM:SS)	Duration (s)	Max Elev. (Deg.)
1	2014:06:06:03:21:42	2014:06:05:20:21:42	178	82.7
2	2014:06:12:08:11:30	2014:06:12:01:11:30	241	55.8
3	2014:06:13:00:52:29	2014:06:1:00:52:29	161	55.3
4	2014:07:21:09:18:10	2014:07:21:02:18:10	270	76.3
5	2014:07:22:16:38:06	2014:07:22:09:38:06	283	78.4
6	2014:09:03:16:06:18	2014:09:03:09:06:18	150	59.6

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File Format (Pass 4)

```
filename,                          OPALS_JPL_20140721,
this file generated,               20160909-141748
generated by,                      Lauren McNally (lauren.mcnally@jpl.nasa.gov),

Elevation,                         76.309309
TxSource,                          OPALS on ISS,
orbit altitude \km,                426.302320
wavelength \nm,                    1550
OGS,                               OCTL,
OGS-height asl \m,                 2200,
location,                          34.380, 117.680,
local date,                        20140721
local time (start of vector),      021810
UTC,                               091810

aperture diameter \mm,             1000,
sampling rate \Hz,                 2000,
sampling resolution \bit,          16,
Duration of Vector \s,             270,

Time\ms,          RxPower\W,       Range\km,        Elevation\degree,
0.000000e+00,     3.099968e-08,    4.945902e+02,    5.536493e+01,
5.000000e-01,     3.292124e-08,    4.945898e+02,    5.536499e+01,
1.000000e+00,     2.841376e-08,    4.945894e+02,    5.536506e+01,
1.500000e+00,     2.381429e-08,    4.945890e+02,    5.536513e+01,
2.000000e+00,     1.123220e-08,    4.945886e+02,    5.536520e+01,
2.500000e+00,     1.982809e-08,    4.945882e+02,    5.536527e+01,
3.000000e+00,     2.087063e-08,    4.945878e+02,    5.536534e+01,
3.500000e+00,     2.164743e-08,    4.945874e+02,    5.536541e+01,
4.000000e+00,     2.354855e-08,    4.945870e+02,    5.536548e+01,
4.500000e+00,     2.300683e-08,    4.945865e+02,    5.536556e+01,
```

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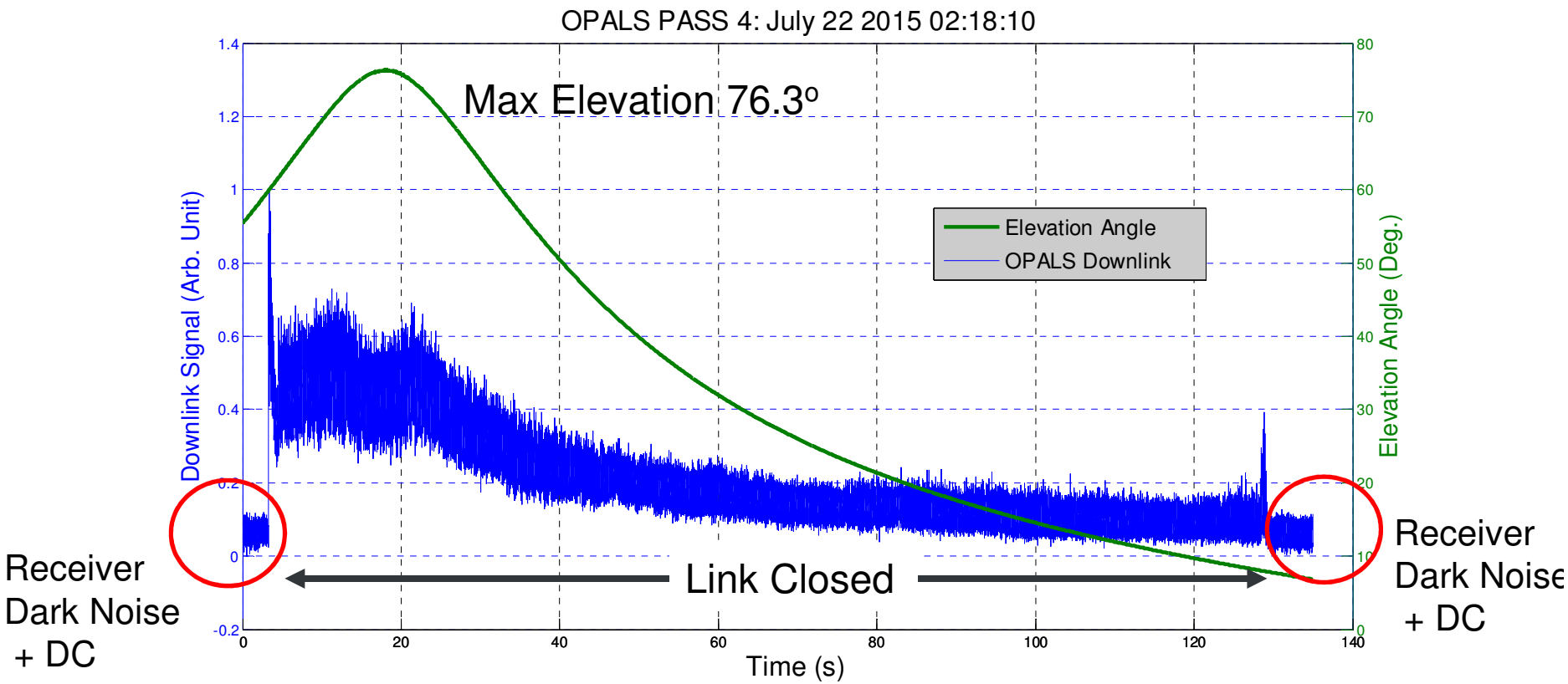
Downlink Pass 4



Link duration 125 s: Initial Elevation Angle 61° Final Elevation Angle 8°
Signal Decreases at lower Elevation Angle

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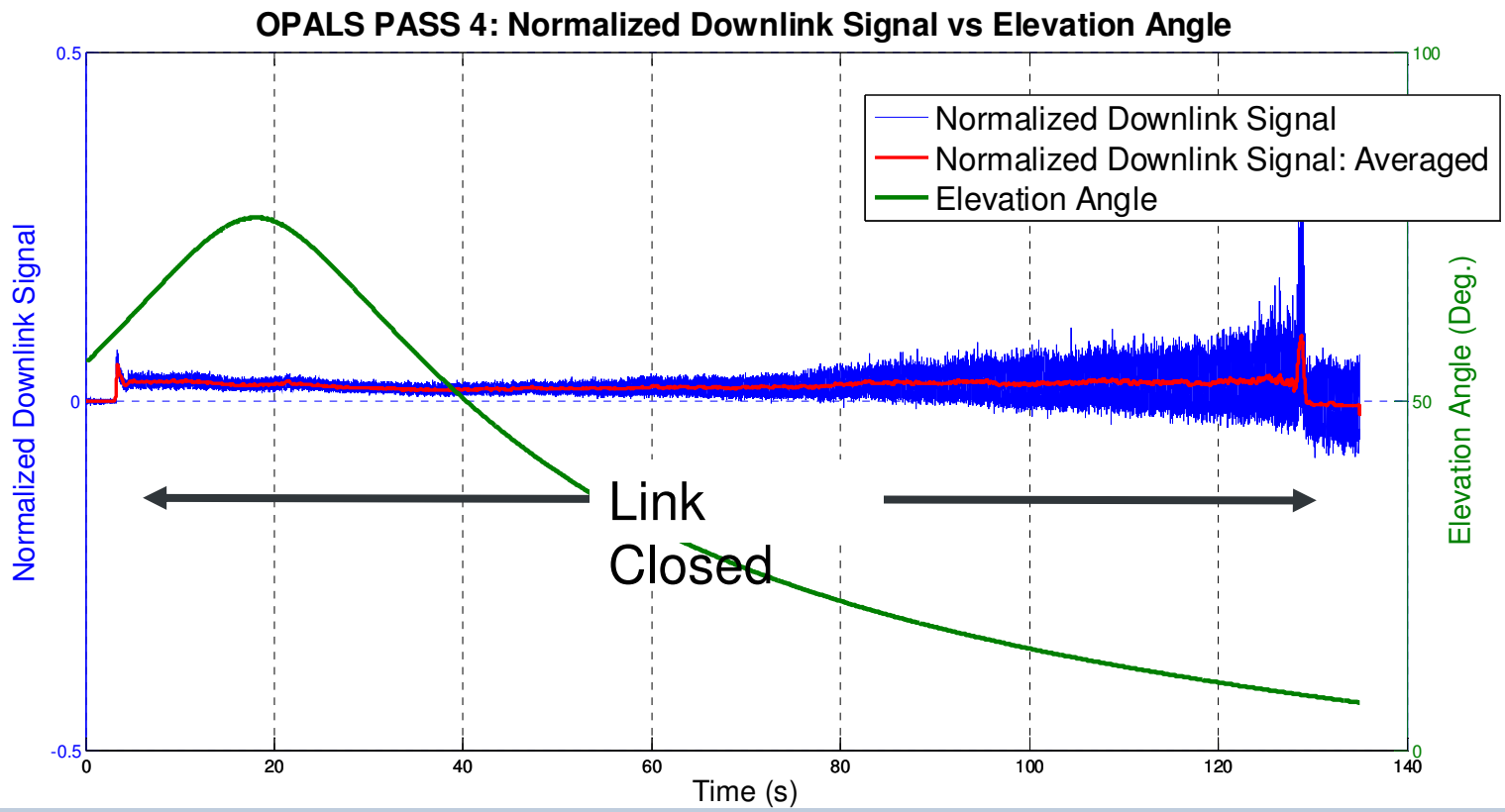
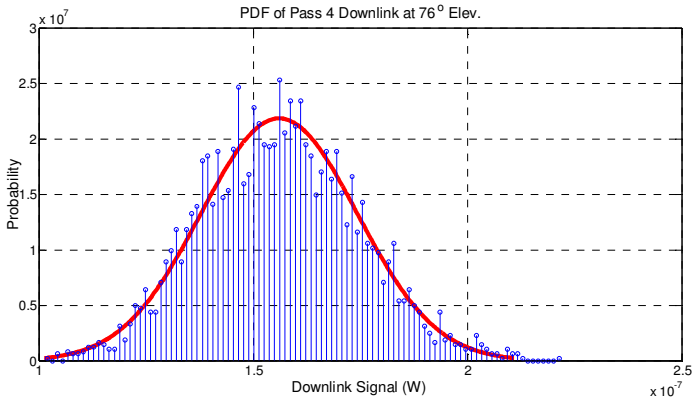
Pass 4: Normalized Downlink Signal

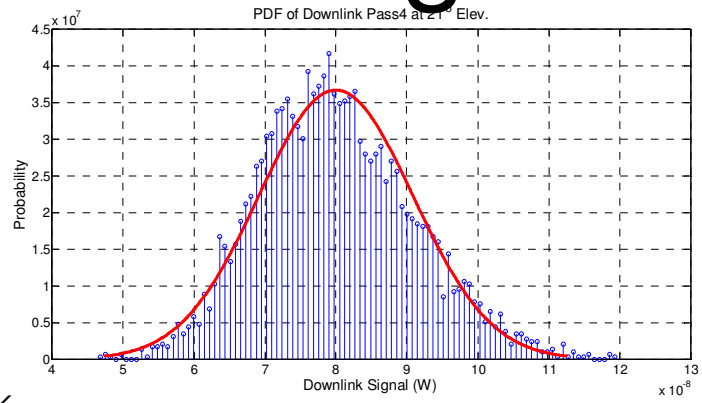
Downlink is Normalized by the Range – Atmospheric Loss
Receiver Dark DC signal is Removed

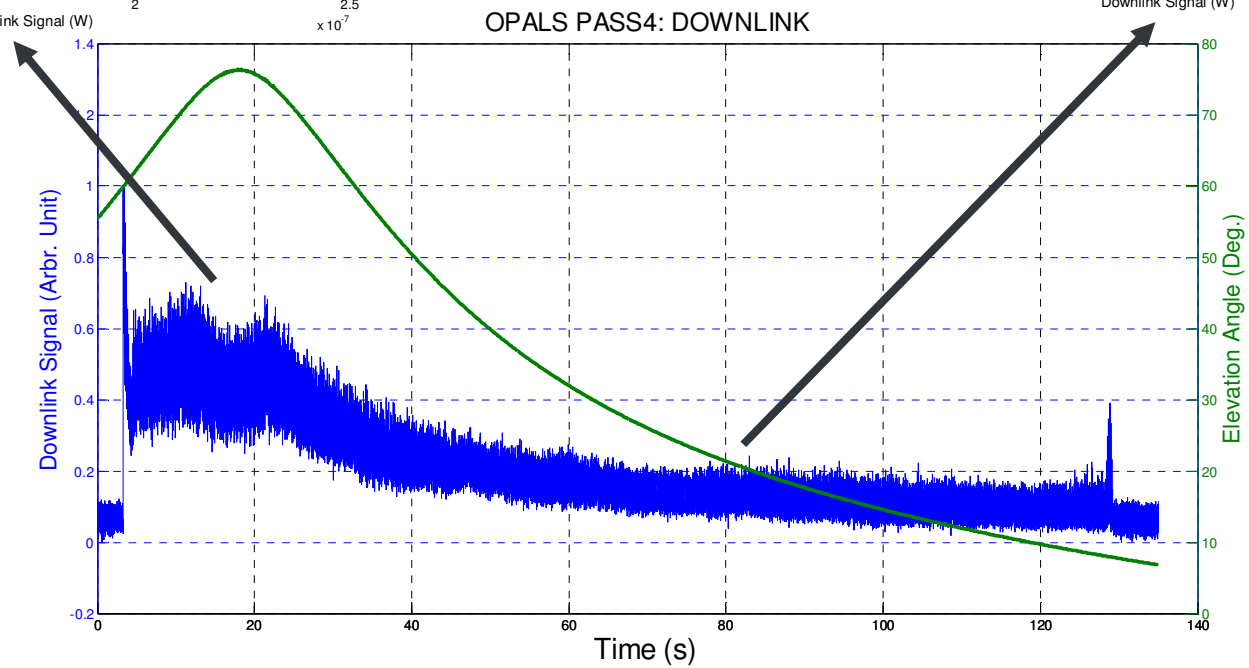


- **The DC Level of the Normalized Downlink Signal is Constant over the link: a very successful link!**
- **Fading is more pronounced at lower elevation angles**

Pass 4: Signal Fading







At different elevation angle fading statistics change due to the different contribution of airmass and detector noise

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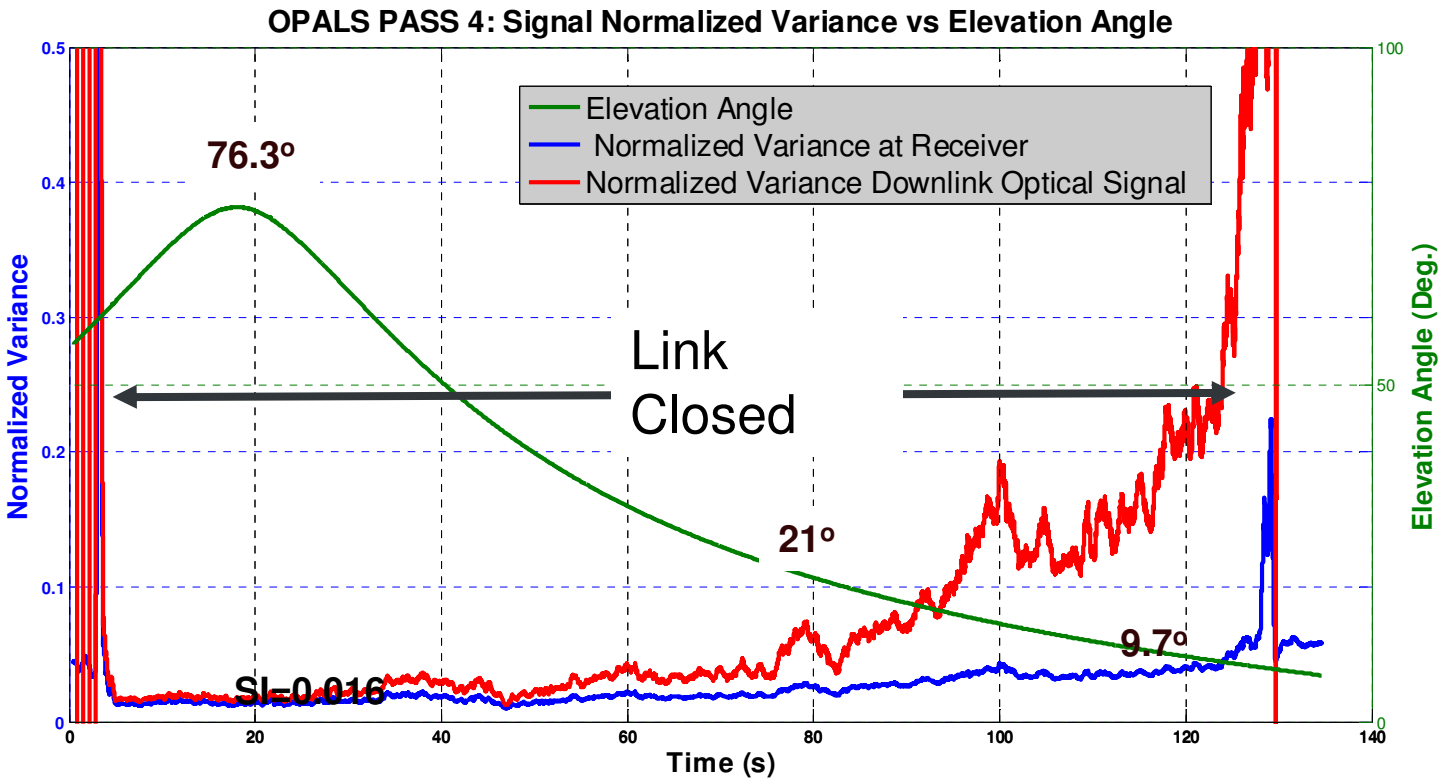
Pass 4: Signal Fading

If the receiver Dark signal component is removed, the normalized variance of the optical downlink signal (aperture averaged scintillation index) is better understood



The scintillation index (optical signal only) increases exponentially at elevation lower than 20°

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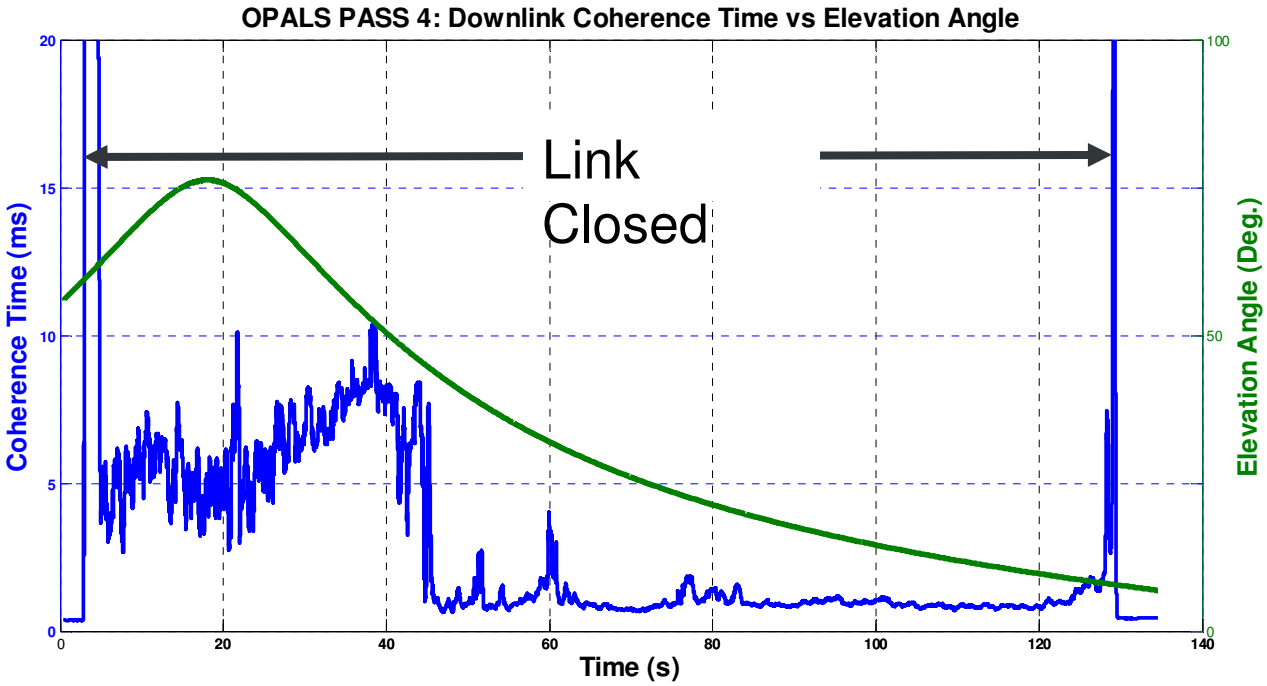
Pass 4: Coherence Time

The evolution of the downlink signal coherence time offer another indication on the dynamic of the signal fading



The coherence time is about 5ms for elevation angle larger than 45°: then drops to around 1ms: cause of this change are under study

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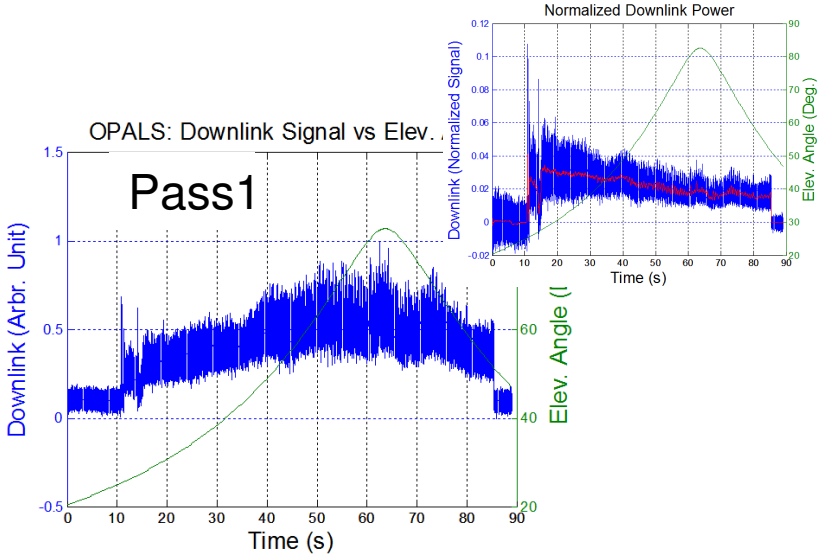
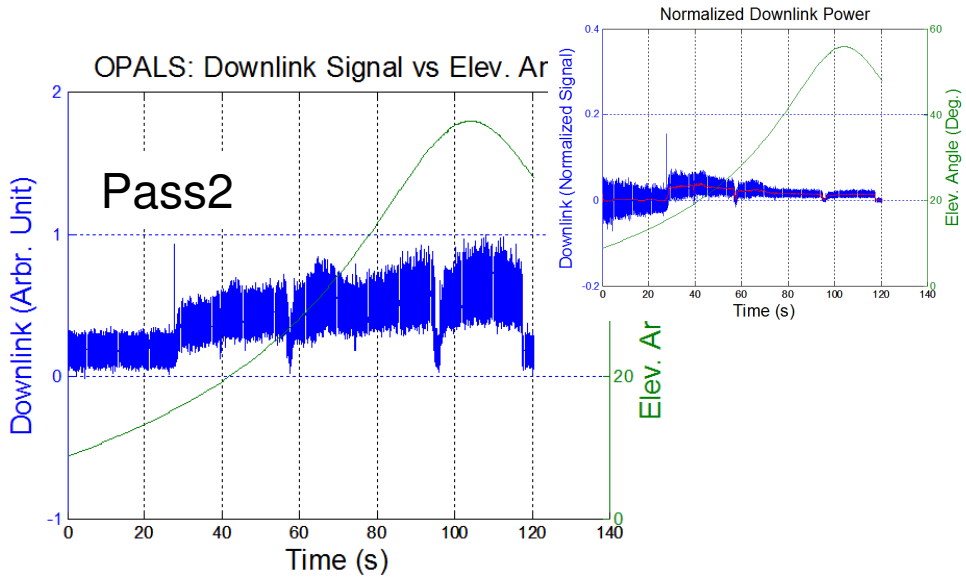
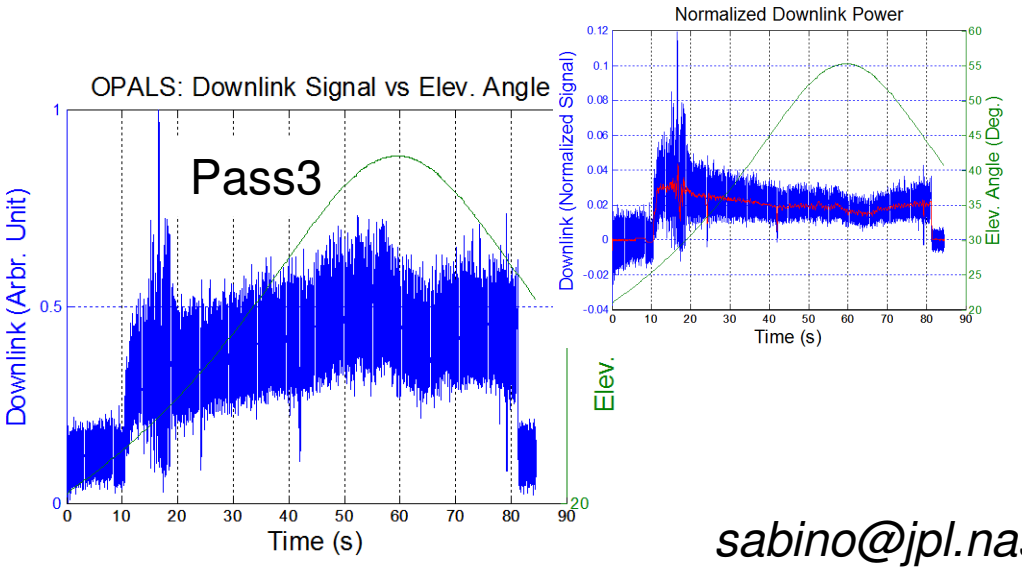
Other Passes







Normalized downlink power better visualizes the ‘quality’ of the link in Pass 1, Pass 2, Pass 3

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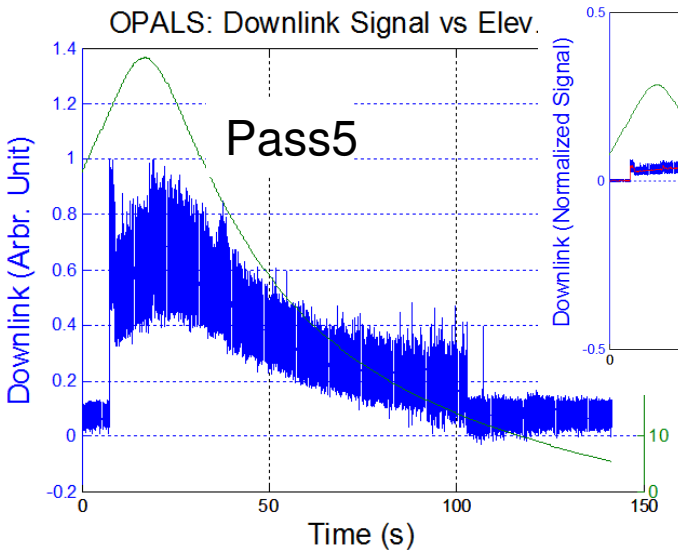
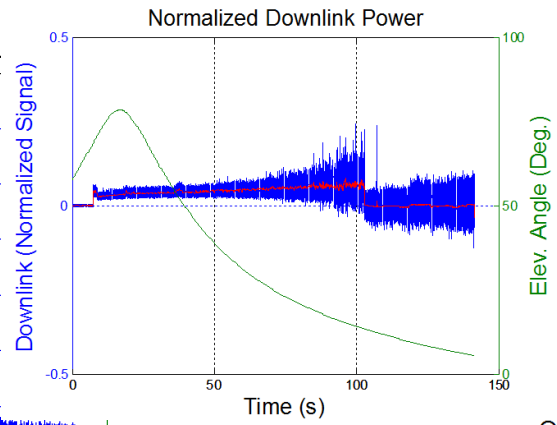
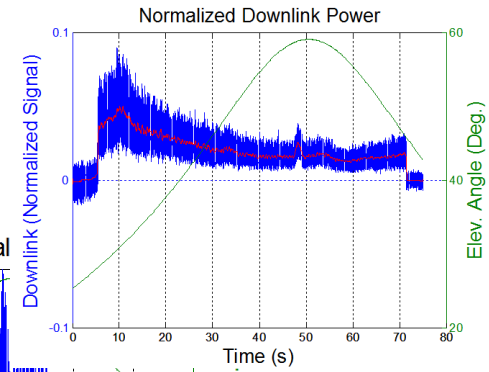
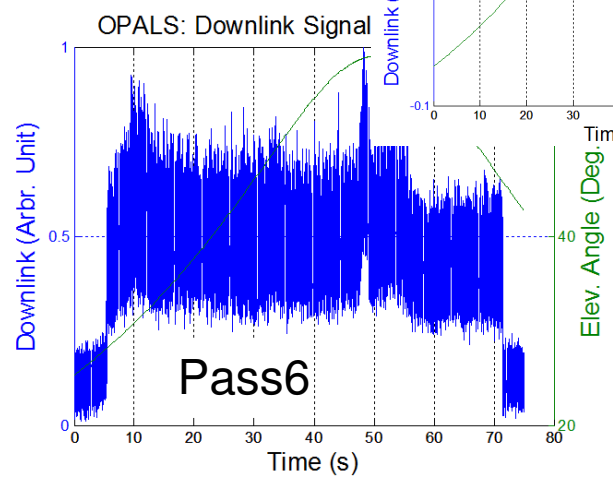
Other Passes (cont'd)









- Pass 4 and Pass 5 appear to be the most successful links.
- Other Links may suffer of drop of power and other discontinuities
- Link performances are still under analysis

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Downlink Summary Table

Figures of Merit at Max El. Angle	Max El Angle (Deg.)	Optical Normalized Variance	Total Normalized Variance	Coherence Time (ms)
Pass 1	82.7	0.032	0.023	8.9
Pass 2	55.8	0.018	0.032	7.6
Pass 3	55.3	0.015	0.024	9.6
Pass 4	76.3	0.013	0.017	4.7
Pass 5	78.4	0.014	0.017	3.5
Pass 6	59.6	0.023	0.037	0.4

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Conclusions

- Six OPALS downlink passes have been formatted according to suggestions from ‘Low Complexity’ study group
  - Pass 4 and Pass 5 appear to best
- Brief discussion of the downlink passes was provided
  - Detector noise affects the statistics at low elevation angle (larger range)
  - Aperture averaged normalized variance varies with elevation angle
  - Coherence time greatly varies during the link
- More detailed analysis will be provided in a journal paper under preparation

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