



CHALMERS



OCEL – Observations of the Chang'E lander with VLBI

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Background

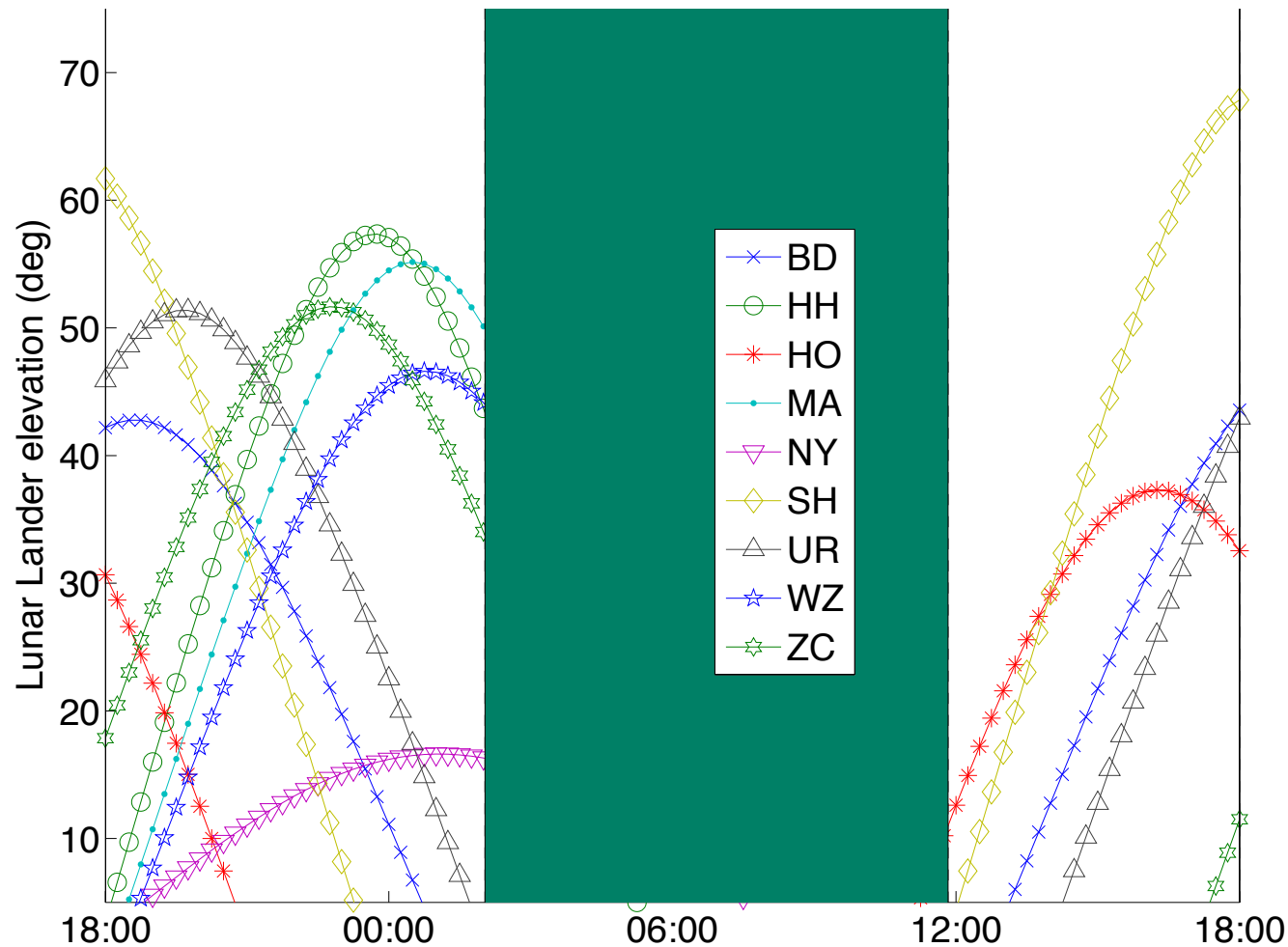
- Tang Geshi and colleagues sent in a proposal in 2014 to observe the Chang'E lander with the IVS network
- Accepted and a series of RD-sessions allocated
- Four sessions per year each in 2014-2015-2016
 - Varying station network
 - Varying availability of lander signal
 - Varying session setup

Scheduling

- General problem: Moon is a near field source
- Standard skd-files will not work, since the RA/DEC information is station-dependent
- Solution in several steps:
 - Preparation of standard schedule with SKED using a “mean Moon” and manually picked observations (next slides)
 - Conversion of skd-file to VEX-file
 - Copying the VEX-file to # VEX-files, one per station
 - Replacement of Lunar lander RA/DEC by station-specific ones
 - Adjusting frequency setup in VEX-files

Scheduling

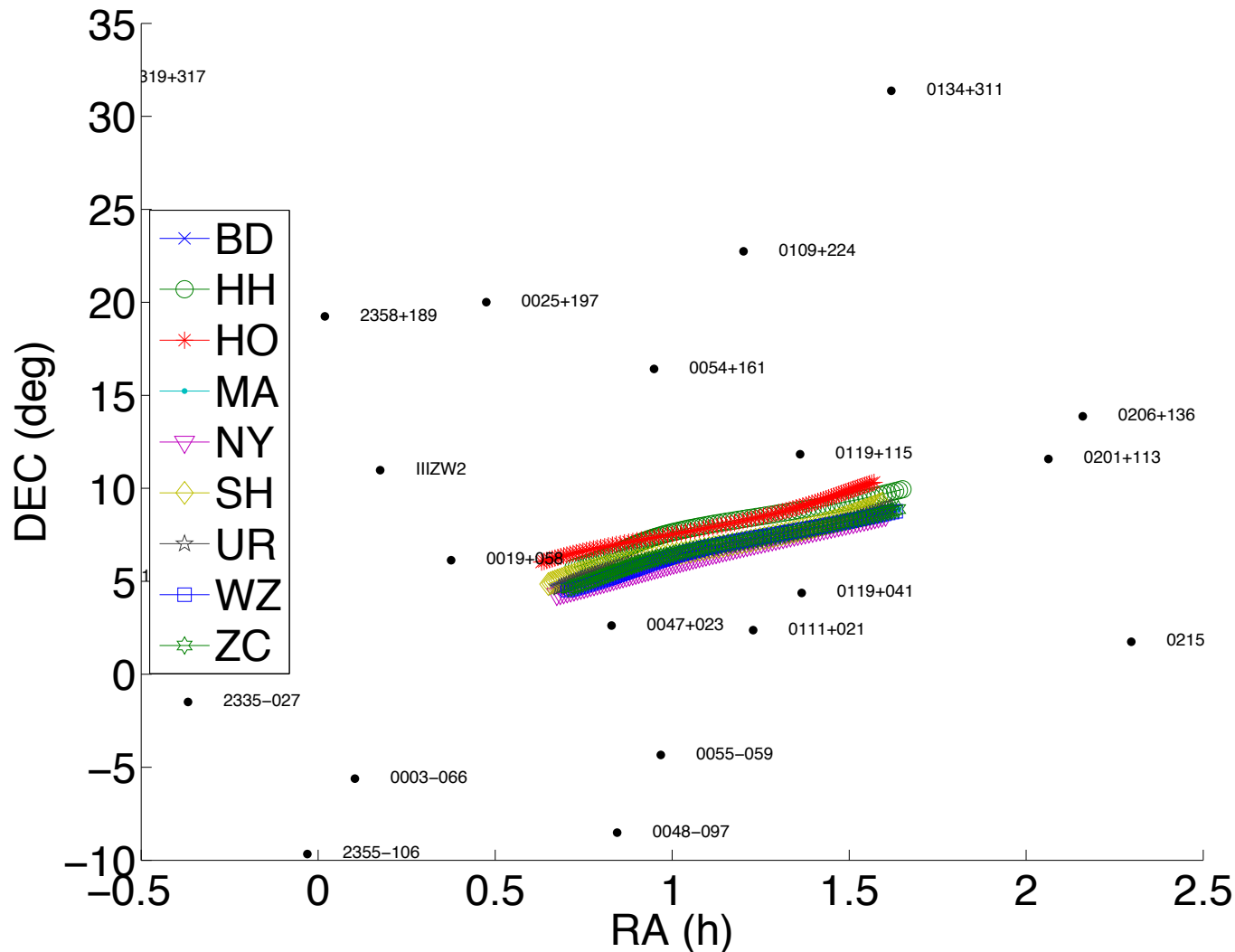
OCEL.02 – 2014, Sep 10/11



OCEL-1 to -4:
long outage
time of the
lunar sender
(green block)

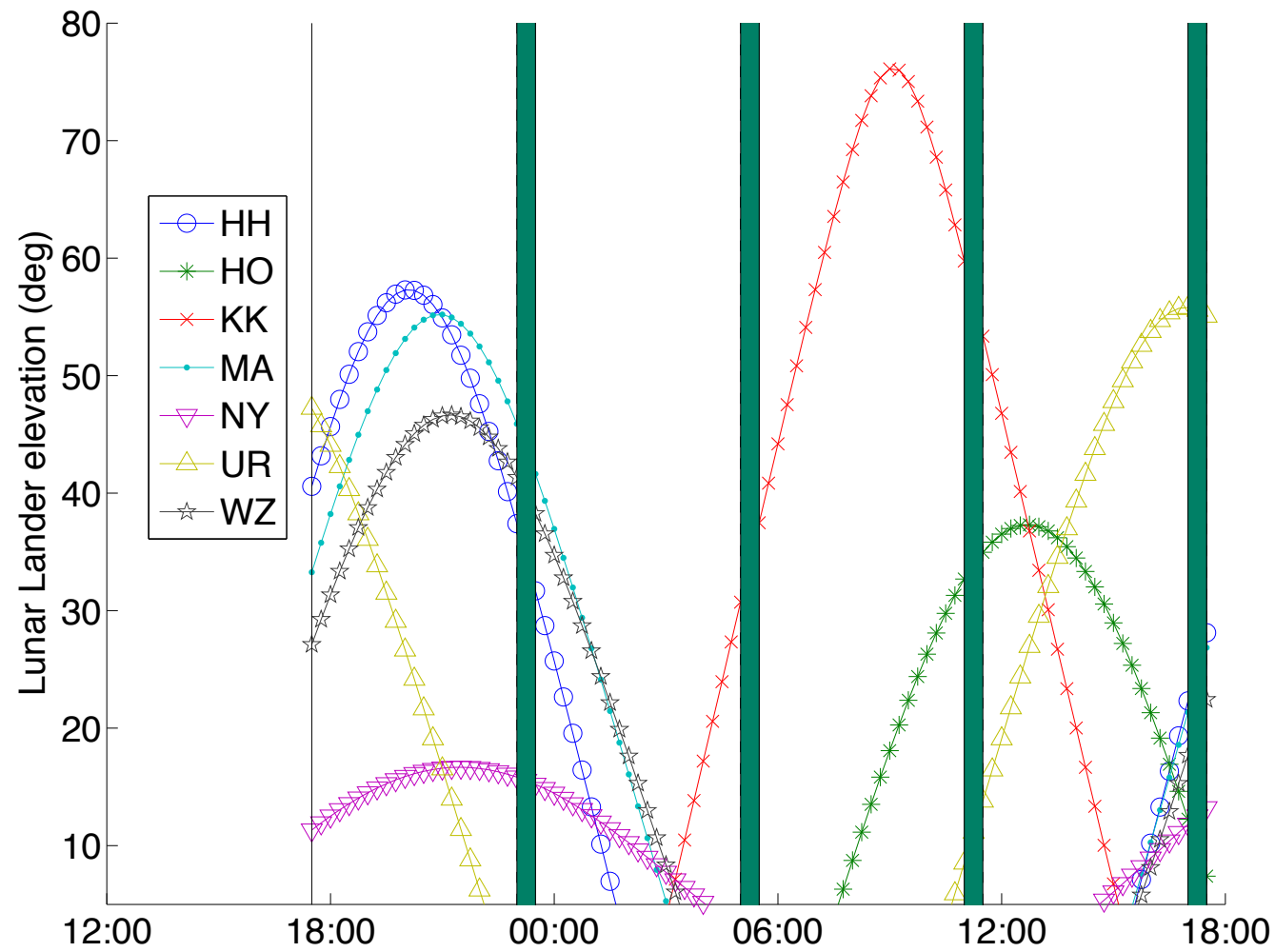
Scheduling

OCEL.02 – 2014, Sep 10/11



RA/DEC are station-specific

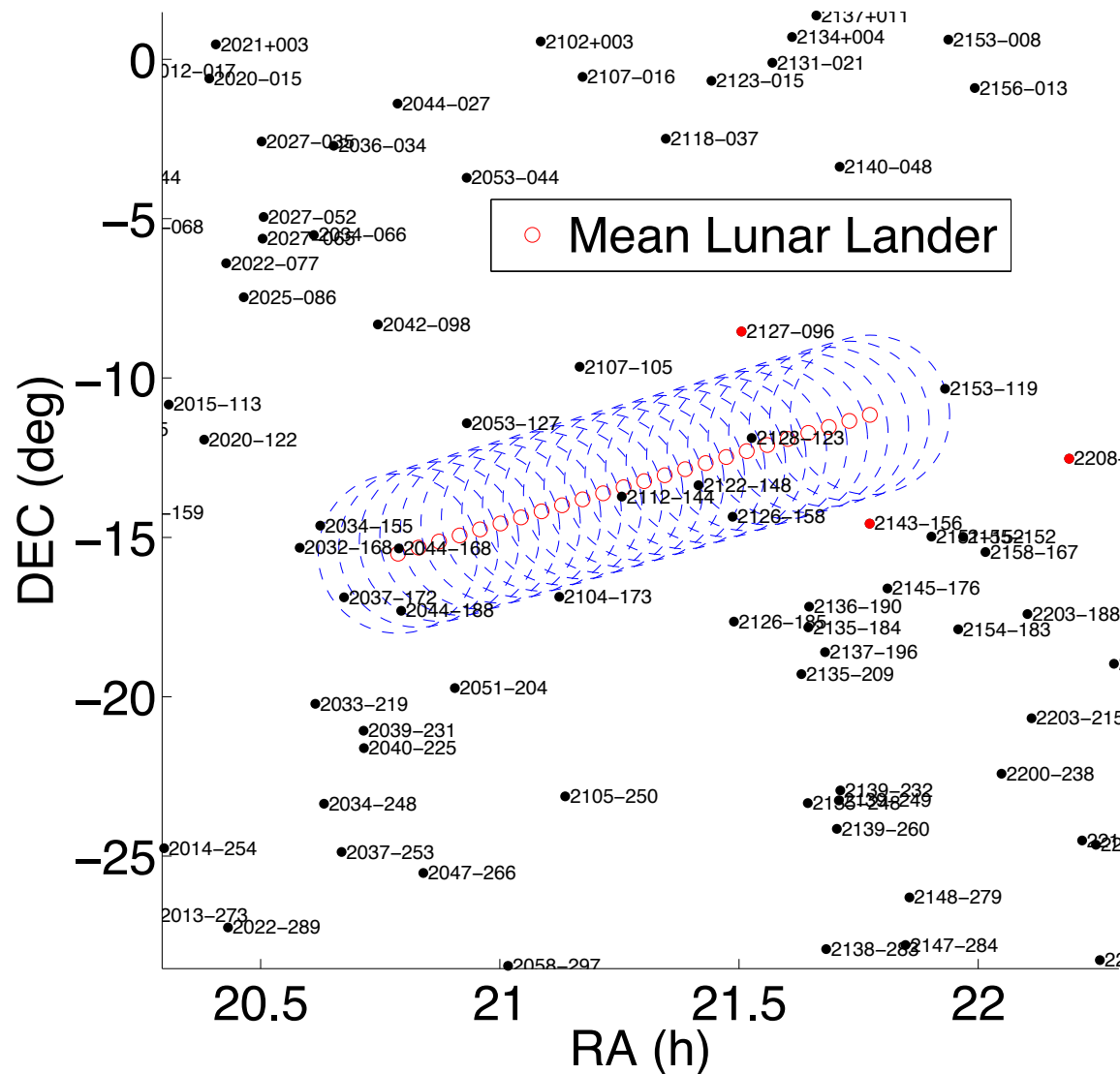
Scheduling



Since OCEL-5:
Outage times
of the sender,
every ca. 6
hours (green
lines)

Scheduling

OCEL-11 / RD.16.09, 2016 Sep 13/14



”close” radio sources added to sked-catalogue

Scheduling approach

- Compromise of two goals:
 - being able to determine clocks and atmospheric parameters, as well as EOP
 - being able to determine lunar lander geodetically and relative to near-by radio sources (phase-referencing), manually picked radio sources in SKED
- => Schedule consisting of “geodetic” and phase-referencing blocks, alternating every 30 min
- Stations that cannot see the Moon perform standard geodetic observations

Scheduling example

Phase referencing PR-01

- 18:00-18:45

- 8 stations: Bd Zc Hh Sh Ur Wz Mc On

- 1 source: 1329-049

Source name	Start yyddd-hhmmss	DURATIONS											
		Ny	Ho	Bd	Zc	Ft	Hh	Sh	Ur	Wz	Mc	Kk	On
OCEL.11	16139-180100			60	60		60	60	60	60	60		30
1329-049	16139-180316			65	65		137	116	158	129	158		158
OCEL.11	16139-180648			30	30		30	30	30	30	30		30
1329-049	16139-180834			65	65		137	116	157	128	157		157
OCEL.11	16139-181206			30	30		30	30	30	30	30		30
1329-049	16139-181352			65	65		136	116	157	127	157		157
OCEL.11	16139-181723			30	30		30	30	30	30	30		30
1329-049	16139-181909			65	65		136	116	156	127	156		156
OCEL.11	16139-182240			30	30		30	30	30	30	30		30
1329-049	16139-182426			64	64		136	115	156	126	156		156
OCEL.11	16139-182757			30	30		30	30	30	30	30		30
1329-049	16139-182943			64	64		135	115	156	125	156		156
OCEL.11	16139-183313			30	30		30	30	30	30	30		30
1329-049	16139-183459			64	64		135	115	155	125	155		155
OCEL.11	16139-183829			30	30		30	30	30	30	30		30
1329-049	16139-184015			64	64		135	115	155	124	155		155
OCEL.11	16139-184345			30	30		30	30	30	30	30		30

The Lunar Lander signal

- S-Band:
 - No ☹️
- X-Band:
 - 8450.75 MHz
 - 8466.15 MHz
 - 8470.00 MHz
 - 8473.85 MHz
 - 8489.25 MHz

Signal transmission needs to be activated. There are 30 min breaks during a 24 h session.

Frequency setup

- Different frequency setups were tested
 - Standard R1 (8 MHz) alternating with special Lunar setups (4 MHz)
 - Standard T2 (4 MHz) alternating with special Lunar setups (4 MHz)
 - For OCEL-11: A special setup (4 MHz) that does avoid frequency switching
- Problems that occurred:
 - Some stations could not switch between wide band and narrow band automatically
 - Some stations require specific Up/Low patching

Example for OCEL-6 frequency setup

```
*-----*
```

```
*----- Frequencies for geodetic observations *
```

```
*-----*
```

```
def GEOSX-SX01;
```

```
  chan_def = &X : 8212.99 MHz : U : 8.000 MHz : &CH01 : &BBC01 : &U_cal;
```

```
  chan_def = &X : 8212.99 MHz : L : 8.000 MHz : &CH02 : &BBC01 : &U_cal;
```

```
  chan_def = &X : 8252.99 MHz : U : 8.000 MHz : &CH03 : &BBC02 : &U_cal;
```

```
  chan_def = &X : 8352.99 MHz : U : 8.000 MHz : &CH04 : &BBC03 : &U_cal;
```

```
  chan_def = &X : 8512.99 MHz : U : 8.000 MHz : &CH05 : &BBC04 : &U_cal;
```

```
  chan_def = &X : 8732.99 MHz : U : 8.000 MHz : &CH06 : &BBC05 : &U_cal;
```

```
  chan_def = &X : 8852.99 MHz : U : 8.000 MHz : &CH07 : &BBC06 : &U_cal;
```

```
  chan_def = &X : 8912.99 MHz : U : 8.000 MHz : &CH08 : &BBC07 : &U_cal;
```

```
  chan_def = &X : 8932.99 MHz : U : 8.000 MHz : &CH09 : &BBC08 : &U_cal;
```

```
  chan_def = &X : 8932.99 MHz : L : 8.000 MHz : &CH10 : &BBC08 : &U_cal;
```

```
  chan_def = &S : 2225.99 MHz : U : 8.000 MHz : &CH11 : &BBC09 : &U_cal;
```

```
  chan_def = &S : 2245.99 MHz : U : 8.000 MHz : &CH12 : &BBC10 : &U_cal;
```

```
  chan_def = &S : 2265.99 MHz : U : 8.000 MHz : &CH13 : &BBC11 : &U_cal;
```

```
  chan_def = &S : 2295.99 MHz : U : 8.000 MHz : &CH14 : &BBC12 : &U_cal;
```

```
  chan_def = &S : 2345.99 MHz : U : 8.000 MHz : &CH15 : &BBC13 : &U_cal;
```

```
  chan_def = &S : 2365.99 MHz : U : 8.000 MHz : &CH16 : &BBC14 : &U_cal;
```

```
  sample_rate = 16.0 Ms/sec;
```

```
enddef;
```

```
*-----*
```

```
*----- Frequencies for OCEL-06 lunar lander observations *
```

```
*-----*
```

```
def LUNSX-SX01;
```

```
  chan_def = &X : 8212.99 MHz : U : 4.000 MHz : &CH01 : &BBC01 : &U_cal;
```

```
  chan_def = &X : 8212.99 MHz : L : 4.000 MHz : &CH02 : &BBC01 : &U_cal;
```

```
  chan_def = &X : 8252.99 MHz : U : 4.000 MHz : &CH03 : &BBC02 : &U_cal;
```

```
*-- aiming at Lunar Lander DOR tones -----*
```

```
  chan_def = &X : 8448.75 MHz : U : 4.000 MHz : &CH04 : &BBC03 : &U_cal;
```

```
  chan_def = &X : 8464.15 MHz : U : 4.000 MHz : &CH05 : &BBC04 : &U_cal;
```

```
  chan_def = &X : 8468.00 MHz : U : 4.000 MHz : &CH06 : &BBC05 : &U_cal;
```

```
  chan_def = &X : 8471.85 MHz : U : 4.000 MHz : &CH07 : &BBC06 : &U_cal;
```

```
  chan_def = &X : 8487.25 MHz : U : 4.000 MHz : &CH08 : &BBC07 : &U_cal;
```

```
  chan_def = &X : 8492.00 MHz : U : 4.000 MHz : &CH09 : &BBC08 : &U_cal;
```

```
  chan_def = &X : 8492.00 MHz : L : 4.000 MHz : &CH10 : &BBC08 : &U_cal;
```

```
*-----*
```

```
  chan_def = &S : 2225.99 MHz : U : 4.000 MHz : &CH11 : &BBC09 : &U_cal;
```

```
  chan_def = &S : 2245.99 MHz : U : 4.000 MHz : &CH12 : &BBC10 : &U_cal;
```

```
  chan_def = &S : 2265.99 MHz : U : 4.000 MHz : &CH13 : &BBC11 : &U_cal;
```

```
  chan_def = &S : 2295.99 MHz : U : 4.000 MHz : &CH14 : &BBC12 : &U_cal;
```

```
  chan_def = &S : 2345.99 MHz : U : 4.000 MHz : &CH15 : &BBC13 : &U_cal;
```

```
  chan_def = &S : 2365.99 MHz : U : 4.000 MHz : &CH16 : &BBC14 : &U_cal;
```

```
  sample_rate = 8.0 Ms/sec;
```

```
enddef;
```

OCEL-11 Frequency setup

```

*----- begin $FREQ          -----*
$FREQ;
def OCEL-SX-SX01;
  chan_def = &X : 8210.05 MHz : U : 4.000 MHz : &CH01 : &BBC01 : &U_cal;
  chan_def = &X : 8210.05 MHz : L : 4.000 MHz : &CH02 : &BBC01 : &U_cal;
  chan_def = &X : 8221.60 MHz : U : 4.000 MHz : &CH03 : &BBC02 : &U_cal;
  chan_def = &X : 8450.75 MHz : U : 4.000 MHz : &CH04 : &BBC03 : &U_cal;
  chan_def = &X : 8466.15 MHz : U : 4.000 MHz : &CH05 : &BBC04 : &U_cal;
  chan_def = &X : 8470.00 MHz : U : 4.000 MHz : &CH06 : &BBC05 : &U_cal;
  chan_def = &X : 8473.85 MHz : U : 4.000 MHz : &CH07 : &BBC06 : &U_cal;
  chan_def = &X : 8489.25 MHz : U : 4.000 MHz : &CH08 : &BBC07 : &U_cal;
  chan_def = &X : 8568.10 MHz : U : 4.000 MHz : &CH09 : &BBC08 : &U_cal;
  chan_def = &X : 8568.10 MHz : L : 4.000 MHz : &CH10 : &BBC08 : &U_cal;
  chan_def = &S : 2212.99 MHz : U : 4.000 MHz : &CH11 : &BBC09 : &U_cal;
  chan_def = &S : 2227.99 MHz : U : 4.000 MHz : &CH12 : &BBC10 : &U_cal;
  chan_def = &S : 2237.99 MHz : U : 4.000 MHz : &CH13 : &BBC11 : &U_cal;
  chan_def = &S : 2267.99 MHz : U : 4.000 MHz : &CH14 : &BBC12 : &U_cal;
  chan_def = &S : 2287.99 MHz : U : 4.000 MHz : &CH15 : &BBC13 : &U_cal;
  chan_def = &S : 2292.99 MHz : U : 4.000 MHz : &CH16 : &BBC14 : &U_cal;
  sample_rate = 8.0 Ms/sec;
enddef;
*----- end $FREQ          -----*

```

Conclusions and Outlook

- So far 11 OCEL sessions scheduled and observed
- OCEL-12 (RD.16.13) upcoming on 19 December
- Different station networks available
 - For some OCEL sessions difficult to fill the “Pacific gap”
- Different frequency setups used
 - For some OCEL sessions problems at some stations switching back and forth
 - Unique OCEL frequency setup since OCEL-11
- Data correlation and data analysis still ongoing