Subject: Measurements of the Feed Probe Efficiency Versus Position
Memo: 3, Rev 2
From: Glen Langston
Date: 2015 July 28

This note describes measurements of the feed probe efficiency with probe position and length. We report results from a series of measurements of the test signal at 1436.5 MHz. These measurements show significant improvement in the feed gain is achieved by proper placement of the feed probe..

These measurements were to diagnosis previously measured high system temperature values.

Test Setup

Before the gain measurements, the electronics components were were tested in laboratory (my cottage). Figure 1 shows a wide-band, single wire antenna connected to a chain of two amplifiers. For the tests, a 800 MHz high pass filter was added before input to the software defined radio dongle. At right in Figure 1 the wave guide probe used for the position test is shown. This probe was a copper wire soldered onto an SMA bulkhead connector. The wire was 7cm long. The waveguide feed is pointed down toward the mirror in the folded horn configuration. The rear of the waveguide is at the top of the waveguide. Before the testing the system gain was found to depend strongly on orientation of the electronics box, probably due to flexing of the component connections. During the tests the orientation of the horn was kept

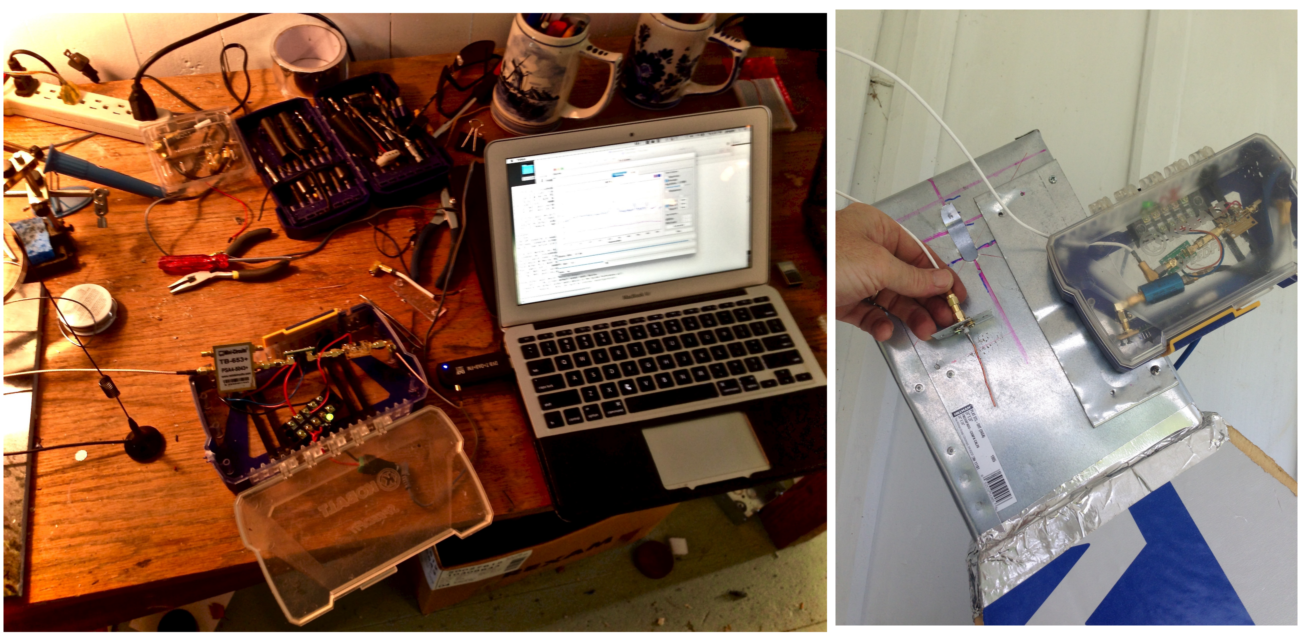

FIGURE 1: AT LEFT THE FEED ELECTRONICS BOX WITH TWO AMPLIFIERS ARE SHOWN IN PREPARATION FOR THE TESTS. THE MACBOOK AIR (CENTER) WAS USED TO RECORD SPECTRA FOR LATER DATA ANALYSIS, BASED ON GNURADIO SOFTWARE. AT RIGHT SHOWS THE FEED PROBE, COPPER WIRE, SHOWN OUTSIDE THE OF THE WAVEGUIDE. THE PROBE POSITION WAS MEASURED FROM THE REAR OF THE WAVEGUIDE, ALONG THE CENTERLINE. THE ELECTRONICS BOX IS MOUNTED PERMANENTLY ON THE WAVEGUIDE, AND A LONG COAXIAL CABLE WAS USED TO ALLOW PROBE MOTIONS. A 0.5 INCH WIDE 2 INCH LONG HOLE IS CUT IN THE SIDE OF THE WAVEGUIDE FOR THE TESTS.

FIGURE 2:AT LEFT, FEED PROBE AND HORN POINTED TOWARDS THE TEST SIGNAL SOURCE. AT RIGHT, WAVEGUIDE MOUNTED ON FOLDED HORN, SIDE VIEW. THE 48IN RULER, LEANING ON THE HORN, SHOWS THE SCALE OF THE SYSTEM. THE COMPUTER AND POWER SUPPLY ARE BEHIND THE HORN.

unchanged. Figure 2 shows the orientation of horn. The feed horn was pointed towards the porch of an adjacent building. Normally the horn is oriented to point toward the sky at a 45 degree elevation. At right in Figure 2 the horn is shown to be tilted towards the ground, to increase the measured test signal strength.

The taper of the horn is set to match the size of an L-band waveguide, 8. inches by 4. inches. More details of the construction and use of the system is described in Light Works Memo 4, along with a summary of the software system used for the tests.

The horn gain and directivity were not fully measured during this test, but clearly the horn was operating roughly as expected, as the signal strength greatly increased when the horn was inclined towards the test source, and significantly reduced as the horn was rotated away from the test source.

The tests were conducted in good weather conditions with a test signal generated by a PC-based USB controlled signal source. The signal source was tuned to 1436.45 MHz, just higher than the radio astronomy frequency band. The receiver system was setup with a 2.1 MHz bandwidth centered on 1436 MHz. Horn was located 40meters from the test signal.

As an aside, some transmitted signals are clearly interfering signals present in this frequency range. The origin of these sources is not known. The interfering signals are seen when the test source is off. No interfering signals were seen in measurements at 1420 MHz, so the signals are not believed to be generated by intermediate frequency aliases.

The telescope consists of a waveguide horn, feed port integrated with waveguide (band-pass) filter, RF electronics box with power supply and a computer for configuring the data acquisition system and receiving spectral data. This configuration is shown schematically in Figure 1.

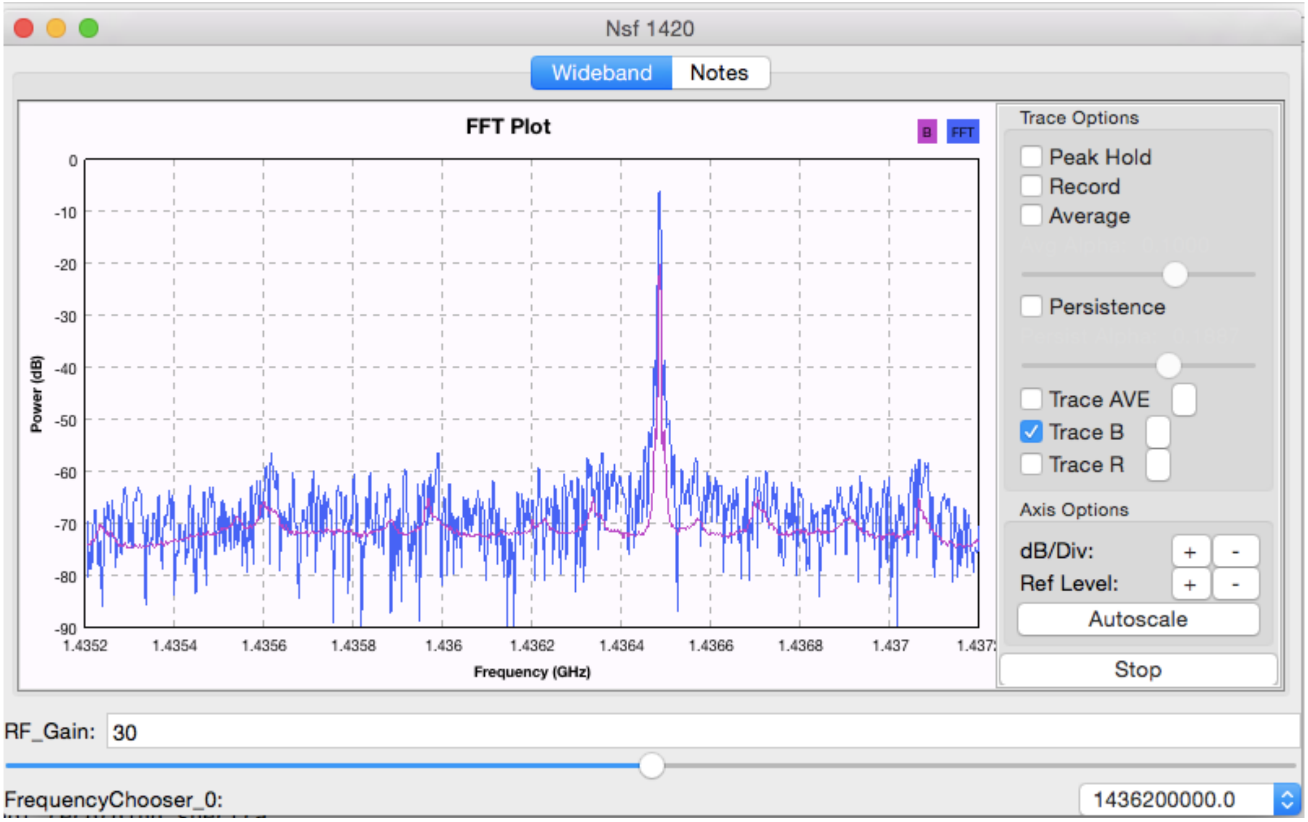

FIGURE 3: INTENSITY VERSUS FREQUENCY PLOT SHOWING THE TEST SIGNAL USED FOR MEASUREMENT OF FEED PROBE PERFORMANCE VERSUS POSITION AND LENGTH. THE INTENSITY AXIS IS IN DB WITH 5 DB PER DIVISION. THE CENTER FREQUENCY IS 1436.2 MHZ AND THE BANDWIDTH IS 2.0 MHZ. THE SMOTHER, RED, CURVE IS A 1 MINUTE AVERAGE AND THE BLUE, NOISIER, CURVE SHOWS A SINGLE 0.0016 SECOND INTEGRATION.

Figure 2 shows profile of the system (left), configuration for an overnight of observations (center) and system inverted for calibration (right).

Figure 3 shows a panel of “NsfRecord”, the program used to record the spectral data. Users of GRC will note the similarities with the base system. The smoother, red, lines shows the test signal in a one minute average of the spectrum over the frequency range 1435.2 to 1437.2 MHz. The test source frequency was 1436.45 MHz, and assumed to have a constant intensity over the time range of these tests. The noisier, blue, line shows a single integration spectrum. The peak intensity was measured for each test position.

Measurements

These measurements were carried out on June 13, 2015 under good weather conditions. The design of the waveguide system is described in Light Work Memo 5. The feed waveguide was designed based on scaling a waveguide band pass filter design for a 14 GHz system.

The waveguide filter port was centered in the wide side of the waveguide. The L-band feed system connects to the horn.

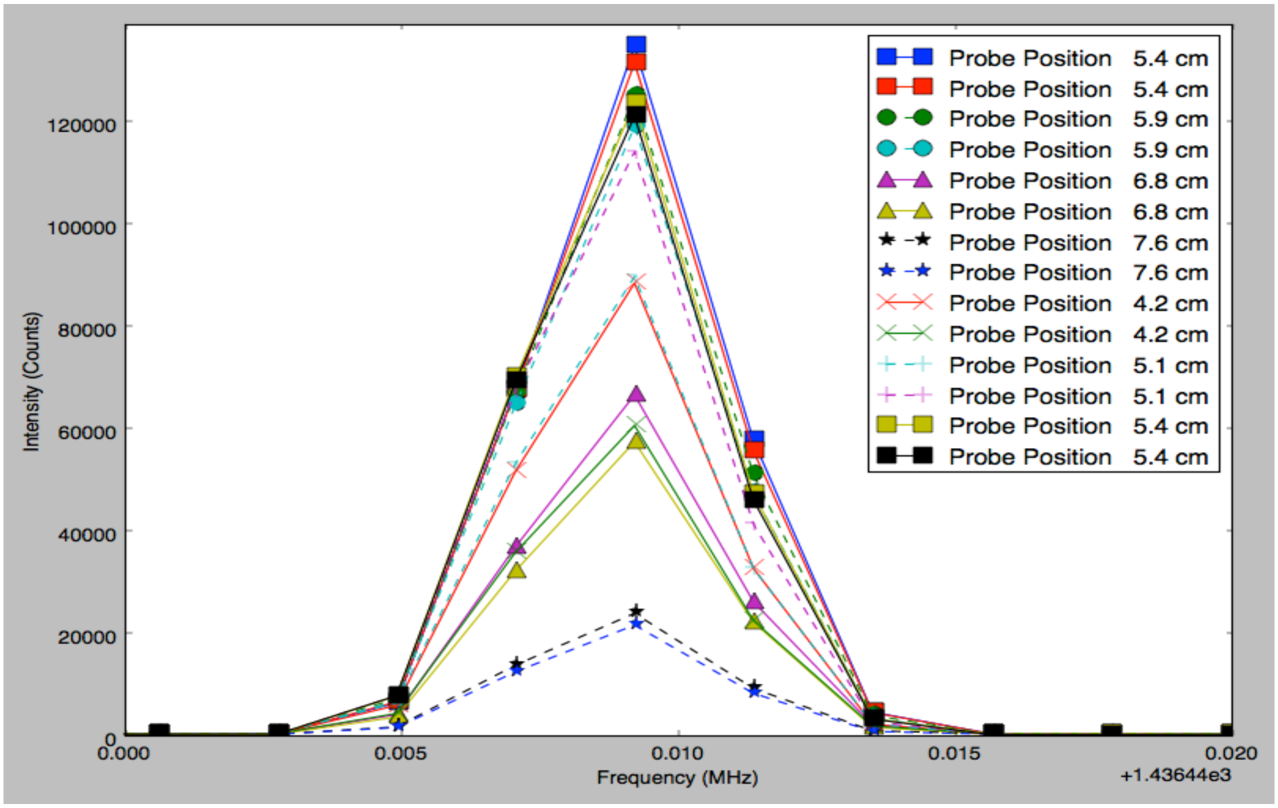

FIGURE 4: MEASUREMENTS OF SYSTEM GAIN AS A FUNCTION OF THE DISTANCE OF THE FEED HORN PROBE FROM THE REAR OF THE WAVEGUIDE. THE PLOTS SHOW INTENSITY VERSUS FREQUENCY FOR A NARROW FREQUENCY RANGE (0.02 MHZ) CENTERED ON THE FREQUENCY OF THE TEST TONE AT 1436.45 MHZ. THE TOP MEASUREMENTS SHOW THE INTENSITY AT ROUGHLY 1/4 WAVELENGTH (21.12/4 = 5.3). AT OTHER DISTANCES THE TEST SIGNAL LEVEL DROPPED. THE FINAL MEASUREMENTS, ALSO AT 5.4CM, SHOW THE GOOD REPEATABILITY OF THE MEASUREMENTS.

Due to the previously reported poor system temperature measurements (Light Work Memos 1 and 2), these measurements of system gain versus feed port properties were performed. For each of the measurements of feed position a pair of 30 second average spectra were recorded. After completing the position measurements the optimum feed position was determined. The position measurements are shown in Figure 4. The optimum length was

The pairs of measurements have the same symbol but different colors. Since it was anticipated that 5.4cm would be the optimum position, this position was measured at the beginning and end of the measurement sequence. Initially the feed probe was located at 6.8cm from the rear of the waveguide. Figure 4 shows that the gain is improved by roughly a factor of two by moving the feed to a distance of 5.4cm..

Next we performed tests of the gain of the system with feed probe length. To perform these tests, the slot in the waveguide was covered with metal tape. A new hole was drilled on the opposite side of the waveguide, at a distance of 5.5cm from the rear of the waveguide. A new feed probe was soldered onto an SMA connector. Thiis probe was a 12 gauge wire 9.5cm long. The feed probe was shortened by 0.5cm and a new pair of measurements were made. The

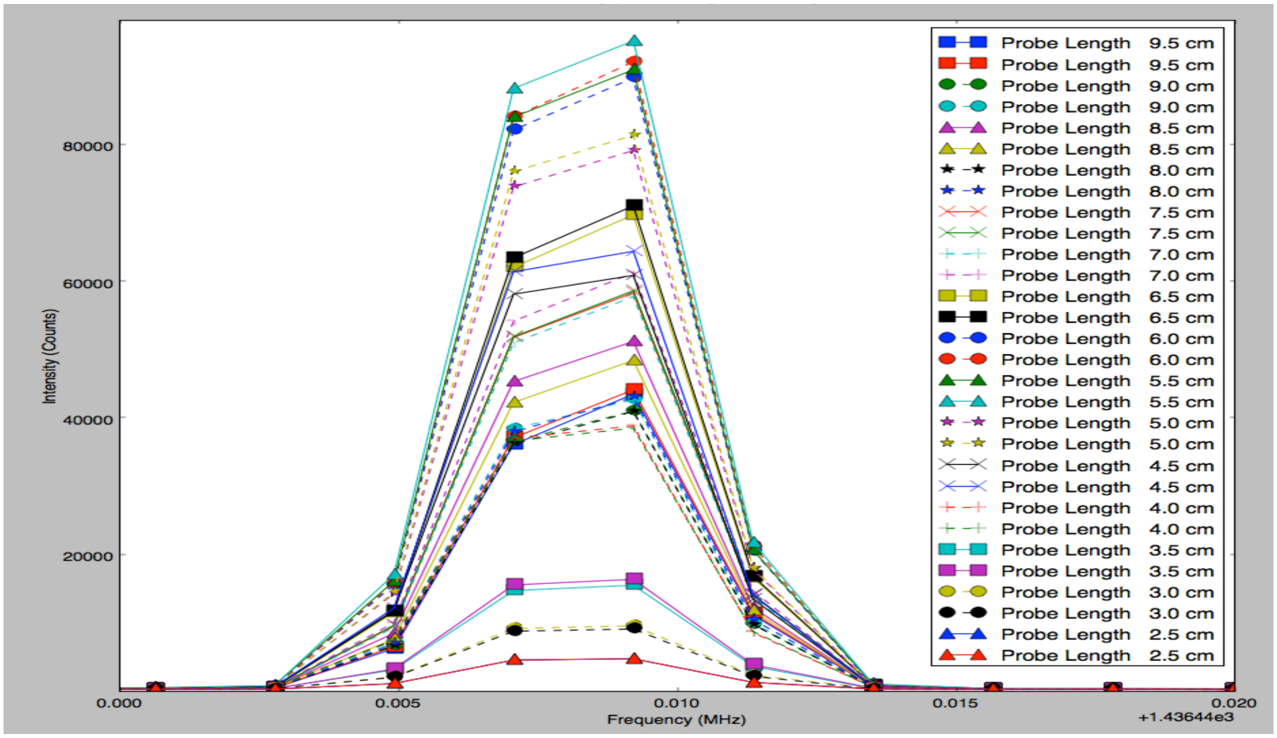

FIGURE 5: MEASUREMENTS OF SYSTEM GAIN AS A FUNCTION OF THE FEED PROBE LENGTH. THE PLOTS SHOW INTENSITY VERSUS FREQUENCY FOR A NARROW FREQUENCY RANGE (0.02 MHZ) CENTERED ON THE FREQUENCY OF THE TEST TONE AT 1436.45 MHZ. FOR THESE TESTS THE FEED PROBE WAS SINGLE 12 GAUGE COPPER WIRE.GRADUALLY SHORTED, IN 5MM INCREMENTS. THE OPTIMUM GAIN WAS FOUND AT A LENGTH OF 5.5CM, VERY CLOSE TO ONE QUARTER WAVELENGTH. THE BOTTOM MOST MEASUREMENTS SHOW THE VERY LOW GAIN OF A 1/8 WAVELENGTH PROBE.

pairs of measurements are shown as small segments of the spectra marked with different symbols in Figure 5. In Figure 5, the test signal for the 9.5cm probe is about 40% of the optimum length, 5.5cm. As the feed probe was shortened the test signal strength increased. Between 6.0 and 5.5cm the test signal reached a maximum, then declined as the probe length decreased. With a length of 2.5cm, lowest test signal strength was roughly 10% of the maximum signal strength.

Conclusions

The position measurement tests showed that the system gain could be maximized by moving the feed probe position to 1/4 wavelength from the rear of the waveguide. The optimum signal strength was found with a feed probe length that was 1/4 of a wavelength long. This is as expected theoretically, but needed to be confirmed experimentally.

Type to enter textProbe Position Measurement Data:
Below is a listing of the processing of the measurements.

```
ESMU.local{glangsto}171: python pltprobepos.py 2015-06-13T16:5*
2015-06-13T17:0*
Argument List: ['pltprobepos.py', '2015-06-13T16:59:40.ast',
'2015-06-13T16:59:55.ast', '2015-06-13T17:00:32.ast',
'2015-06-13T17:00:47.ast', '2015-06-13T17:01:23.ast',
'2015-06-13T17:01:38.ast', '2015-06-13T17:02:18.ast',
'2015-06-13T17:02:33.ast', '2015-06-13T17:03:18.ast',
'2015-06-13T17:03:33.ast', '2015-06-13T17:04:05.ast',
'2015-06-13T17:04:20.ast', '2015-06-13T17:06:18.ast',
'2015-06-13T17:06:34.ast']
File: 2015-06-13T16:59:40.ast
 Max:  134930.9  Median:     591.9 SNR: 227.94 ; 257 Probe Position   5.4 cm
# Feed probe lambda/4; position test

1435.1 1437.297851
File: 2015-06-13T16:59:55.ast
 Max:  131652.5  Median:     549.9 SNR: 239.40 ; 257 Probe Position   5.4 cm
File: 2015-06-13T17:00:32.ast
 Max:  125279.4  Median:     520.8 SNR: 240.54 ; 257 Probe Position   5.9 cm
File: 2015-06-13T17:00:47.ast
 Max:  119257.5  Median:     507.3 SNR: 235.06 ; 257 Probe Position   5.9 cm
File: 2015-06-13T17:01:23.ast
 Max:   66849.8  Median:     619.2 SNR: 107.97 ; 257 Probe Position   6.8 cm
File: 2015-06-13T17:01:38.ast
 Max:   57680.6  Median:     514.7 SNR: 112.06 ; 257 Probe Position   6.8 cm
File: 2015-06-13T17:02:18.ast
 Max:   24198.3  Median:     732.9 SNR:  33.02 ; 257 Probe Position   7.6 cm
File: 2015-06-13T17:02:33.ast
 Max:   21891.0  Median:     727.5 SNR:  30.09 ; 257 Probe Position   7.6 cm
File: 2015-06-13T17:03:18.ast
 Max:   88665.8  Median:     619.0 SNR: 143.25 ; 257 Probe Position   4.2 cm
File: 2015-06-13T17:03:33.ast
 Max:   60865.6  Median:     768.3 SNR:  79.22 ; 257 Probe Position   4.2 cm
File: 2015-06-13T17:04:05.ast
 Max:   89955.5  Median:     613.0 SNR: 146.74 ; 257 Probe Position   5.1 cm
File: 2015-06-13T17:04:20.ast
 Max:  114321.4  Median:     488.3 SNR: 234.10 ; 257 Probe Position   5.1 cm
File: 2015-06-13T17:06:18.ast
 Max:  123791.1  Median:     482.7 SNR: 256.47 ; 257 Probe Position   5.4 cm
File: 2015-06-13T17:06:34.ast
 Max:  121271.3  Median:     484.8 SNR: 250.13 ; 257 Probe Position   5.4 cm
```

Probe Position Measurement Data:

Below is a listing of the processing of the measurements.

```
ESMU.local{glangsto}171: python pltprobepos.py 2015-06-13T16:5* 2015-06-13T17:0*
Argument List: ['pltprobepos.py', '2015-06-13T16:59:40.ast',
'2015-06-13T16:59:55.ast', '2015-06-13T17:00:32.ast', '2015-06-13T17:00:47.ast',
'2015-06-13T17:01:23.ast', '2015-06-13T17:01:38.ast', '2015-06-13T17:02:18.ast',
'2015-06-13T17:02:33.ast', '2015-06-13T17:03:18.ast', '2015-06-13T17:03:33.ast',
'2015-06-13T17:04:05.ast', '2015-06-13T17:04:20.ast', '2015-06-13T17:06:18.ast',
'2015-06-13T17:06:34.ast']
File: 2015-06-13T16:59:40.ast
 Max:  134930.9  Median:     591.9 SNR: 227.94 ; 257 Probe Position   5.4 cm
# Feed probe lambda/4; position test

1435.1 1437.297851
File: 2015-06-13T16:59:55.ast
 Max:  131652.5  Median:     549.9 SNR: 239.40 ; 257 Probe Position   5.4 cm
```

Probe Length Measurement Data

```
ESMU.local{glangsto}172: python pltprobelength.py 2015-06-13T18*
2015-06-13T19:0*
Argument List: ['pltprobelength.py', '2015-06-13T18:32:24.ast',
'2015-06-13T18:32:39.ast', '2015-06-13T18:36:14.ast',
'2015-06-13T18:36:29.ast', '2015-06-13T18:37:22.ast',
'2015-06-13T18:37:37.ast', '2015-06-13T18:38:36.ast',
'2015-06-13T18:38:51.ast', '2015-06-13T18:39:39.ast',
'2015-06-13T18:39:54.ast', '2015-06-13T18:40:55.ast',
'2015-06-13T18:41:10.ast', '2015-06-13T18:42:05.ast',
'2015-06-13T18:42:20.ast', '2015-06-13T18:44:19.ast',
'2015-06-13T18:44:34.ast', '2015-06-13T18:45:41.ast',
'2015-06-13T18:45:56.ast', '2015-06-13T18:47:03.ast',
'2015-06-13T18:47:19.ast', '2015-06-13T18:48:38.ast',
'2015-06-13T18:48:53.ast', '2015-06-13T18:49:53.ast',
'2015-06-13T18:50:08.ast', '2015-06-13T18:51:11.ast',
'2015-06-13T18:51:26.ast', '2015-06-13T18:52:25.ast',
'2015-06-13T18:52:40.ast', '2015-06-13T18:53:49.ast',
'2015-06-13T18:54:04.ast']
File: 2015-06-13T18:32:24.ast
 Max:   43569.5  Median:     387.1 SNR: 112.57 ; 257 Probe Length   9.5 cm
# Test of long probe length; El=lenght cm 1435.1 1437.297851
File: 2015-06-13T18:32:39.ast
 Max:   44214.9  Median:     388.9 SNR: 113.69 ; 257 Probe Length   9.5 cm
File: 2015-06-13T18:36:14.ast
 Max:   41089.6  Median:     336.9 SNR: 121.96 ; 257 Probe Length   9.0 cm
File: 2015-06-13T18:36:29.ast
 Max:   42766.0  Median:     337.9 SNR: 126.55 ; 257 Probe Length   9.0 cm
File: 2015-06-13T18:37:22.ast
 Max:   51284.5  Median:     333.5 SNR: 153.77 ; 257 Probe Length   8.5 cm
File: 2015-06-13T18:37:37.ast
 Max:   48501.9  Median:     335.7 SNR: 144.49 ; 257 Probe Length   8.5 cm
File: 2015-06-13T18:38:36.ast
 Max:   41019.6  Median:     378.8 SNR: 108.29 ; 257 Probe Length   8.0 cm
File: 2015-06-13T18:38:51.ast
 Max:   43078.2  Median:     381.1 SNR: 113.05 ; 257 Probe Length   8.0 cm
File: 2015-06-13T18:39:39.ast
 Max:   58400.0  Median:     351.5 SNR: 166.16 ; 257 Probe Length   7.5 cm
File: 2015-06-13T18:39:54.ast
 Max:   58693.7  Median:     357.8 SNR: 164.02 ; 257 Probe Length   7.5 cm
File: 2015-06-13T18:40:55.ast
 Max:   57821.8  Median:     336.0 SNR: 172.07 ; 257 Probe Length   7.0 cm
File: 2015-06-13T18:41:10.ast
 Max:   61312.7  Median:     336.3 SNR: 182.31 ; 257 Probe Length   7.0 cm
File: 2015-06-13T18:42:05.ast
 Max:   69803.5  Median:     334.8 SNR: 208.47 ; 257 Probe Length   6.5 cm
File: 2015-06-13T18:42:20.ast
 Max:   71115.8  Median:     330.1 SNR: 215.43 ; 257 Probe Length   6.5 cm
File: 2015-06-13T18:44:19.ast
 Max:   89844.9  Median:     324.8 SNR: 276.59 ; 257 Probe Length   6.0 cm
File: 2015-06-13T18:44:34.ast
 Max:   92189.7  Median:     326.7 SNR: 282.18 ; 257 Probe Length   6.0 cm
File: 2015-06-13T18:45:41.ast
 Max:   91015.0  Median:     463.2 SNR: 196.50 ; 257 Probe Length   5.5 cm
File: 2015-06-13T18:45:56.ast
 Max:   95244.3  Median:     452.9 SNR: 210.30 ; 257 Probe Length   5.5 cm
File: 2015-06-13T18:47:03.ast
```

```
 Max:   79204.4  Median:     379.9 SNR: 208.50 ; 257 Probe Length   5.0 cm
File: 2015-06-13T18:47:19.ast
 Max:   81433.7  Median:     382.1 SNR: 213.11 ; 257 Probe Length   5.0 cm
File: 2015-06-13T18:48:38.ast
 Max:   60933.5  Median:     401.1 SNR: 151.91 ; 257 Probe Length   4.5 cm
File: 2015-06-13T18:48:53.ast
 Max:   64451.9  Median:     397.1 SNR: 162.32 ; 257 Probe Length   4.5 cm
File: 2015-06-13T18:49:53.ast
 Max:   38919.8  Median:     431.2 SNR:  90.25 ; 257 Probe Length   4.0 cm
File: 2015-06-13T18:50:08.ast
 Max:   38593.7  Median:     429.2 SNR:  89.91 ; 257 Probe Length   4.0 cm
File: 2015-06-13T18:51:11.ast
 Max:   15615.5  Median:     418.1 SNR:  37.35 ; 257 Probe Length   3.5 cm
File: 2015-06-13T18:51:26.ast
 Max:   16475.1  Median:     424.2 SNR:  38.83 ; 257 Probe Length   3.5 cm
File: 2015-06-13T18:52:25.ast
 Max:    9675.6  Median:     416.0 SNR:  23.26 ; 257 Probe Length   3.0 cm
File: 2015-06-13T18:52:40.ast
Max:    9208.7  Median:     415.1 SNR:  22.18 ; 257 Probe Length   3.0 cm
File: 2015-06-13T18:53:49.ast
 Max:    4864.4  Median:     410.0 SNR:  11.86 ; 256 Probe Length   2.5 cm
File: 2015-06-13T18:54:04.ast
 Max:    4851.7  Median:     409.7 SNR:  11.84 ; 257 Probe Length   2.5 cm
```