40m Laboratory Upgrade Progress Report

LSC meeting at LIGO Livingston observatory

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LIGO-G040081-00-R

40m Team:

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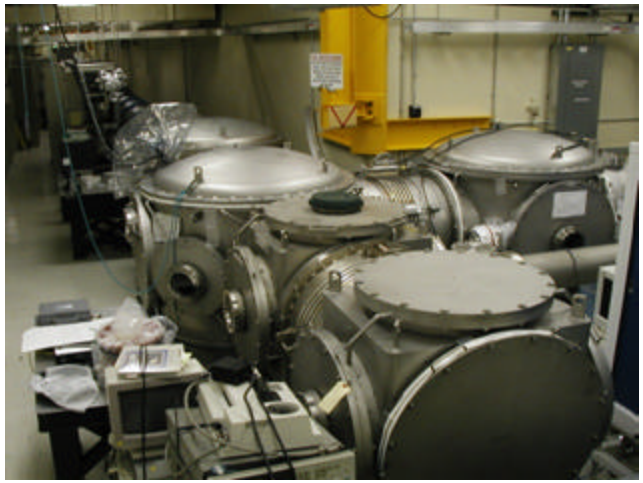
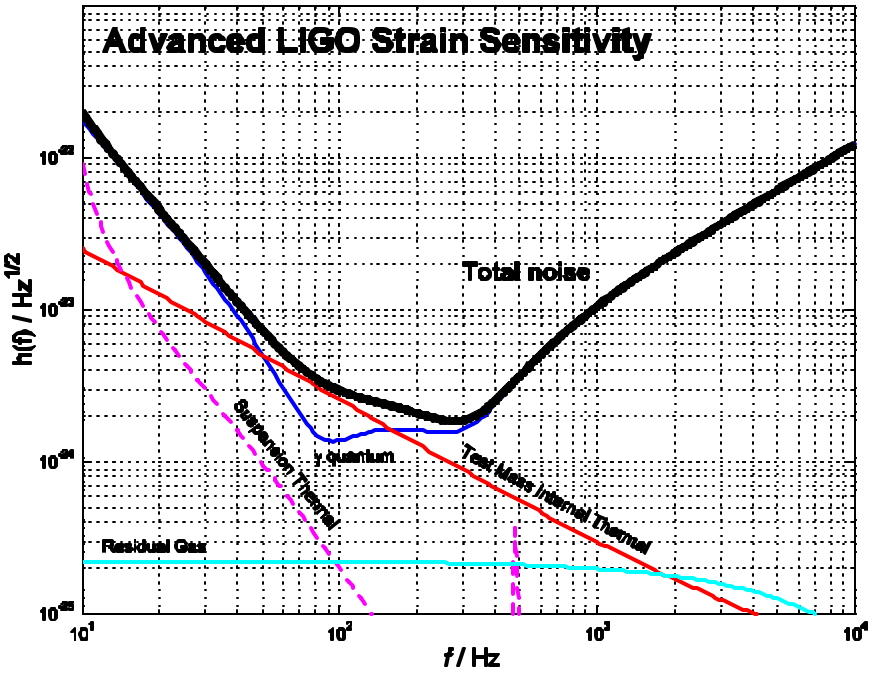
Objectives

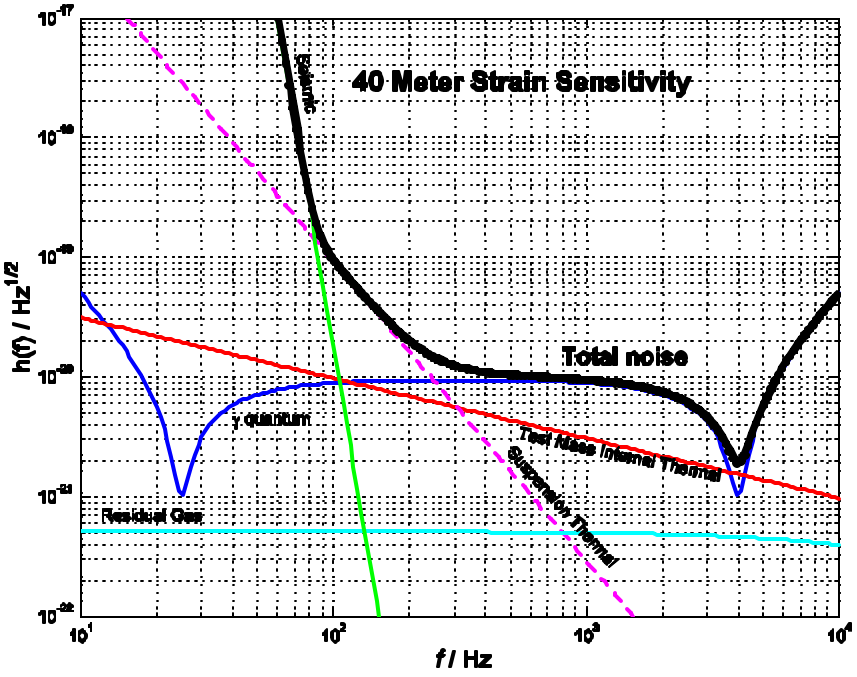
- Develop **lock acquisition procedure** of detuned Resonant Sideband Extraction (RSE),
- Characterize noise mechanism,
- Verify optical spring effect,
- Develop DC readout scheme,
- etc.

for Advanced LIGO, LCGT,
and other future GW detectors



Target Sensitivity of Advanced LIGO and 40m

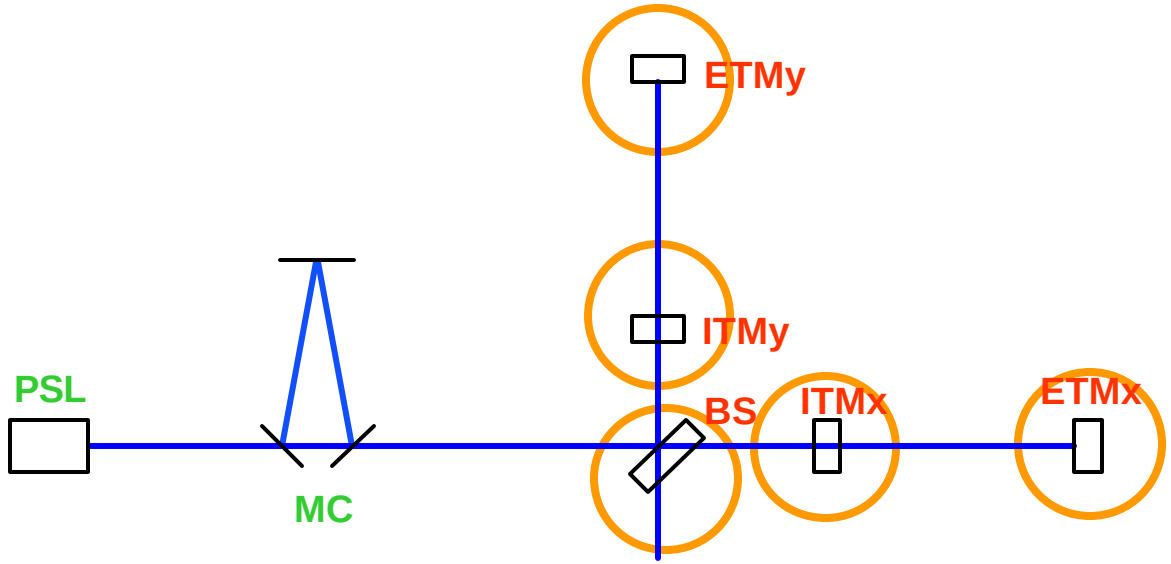




Important Achievement (1)
Installation of FP Michelson

September, 2003

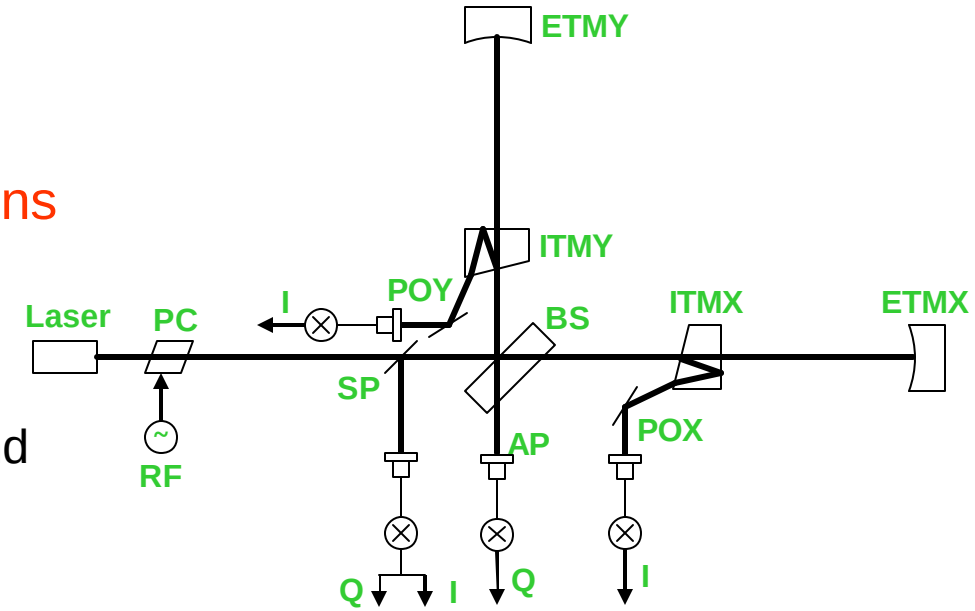
- Four TMs and BS: installed



Important Achievement (2)
Lock Acquisition of FP Michelson

November 2003

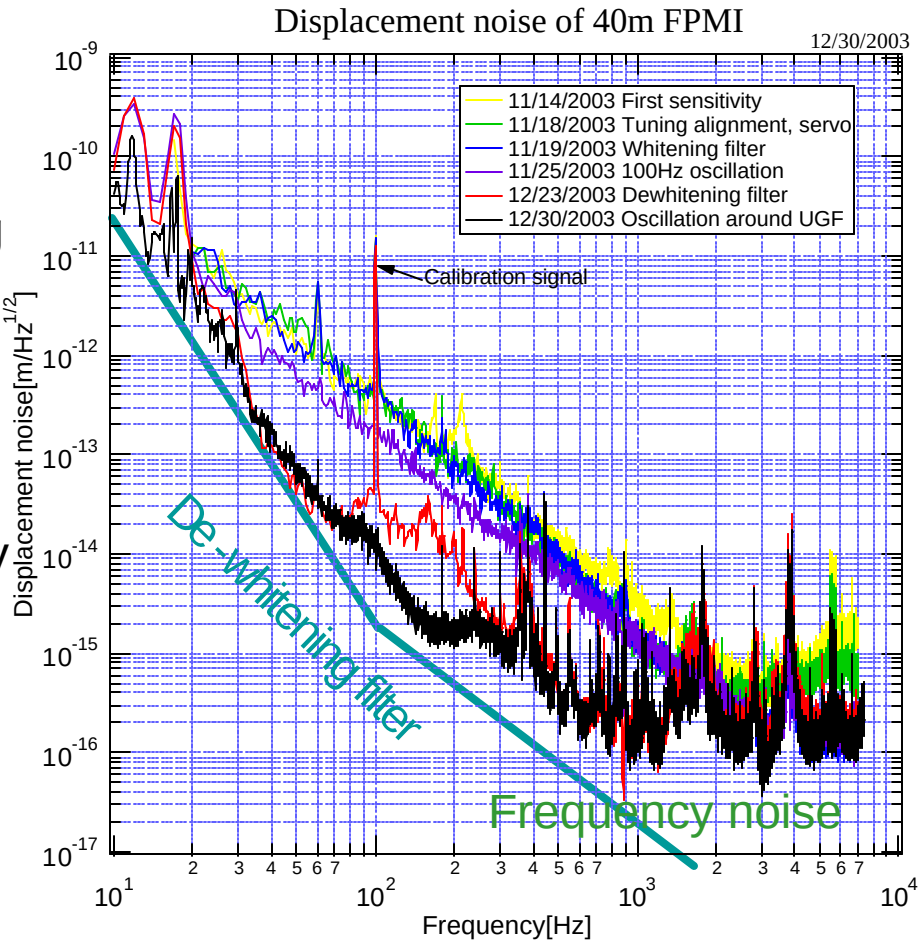
- FP Michelson locked
- Arms locked independently, and switched to common/differential servo
- Digitally controlled suspensions
- Finesse ~ 1200
- Seismic motion ~ 10 - 100 times noisier than LIGO site
- UGF ~ 300Hz (limited by A/D and D/A speed)



Important Achievement (3) Spectrum of FP Michelson

November ~ December 2003

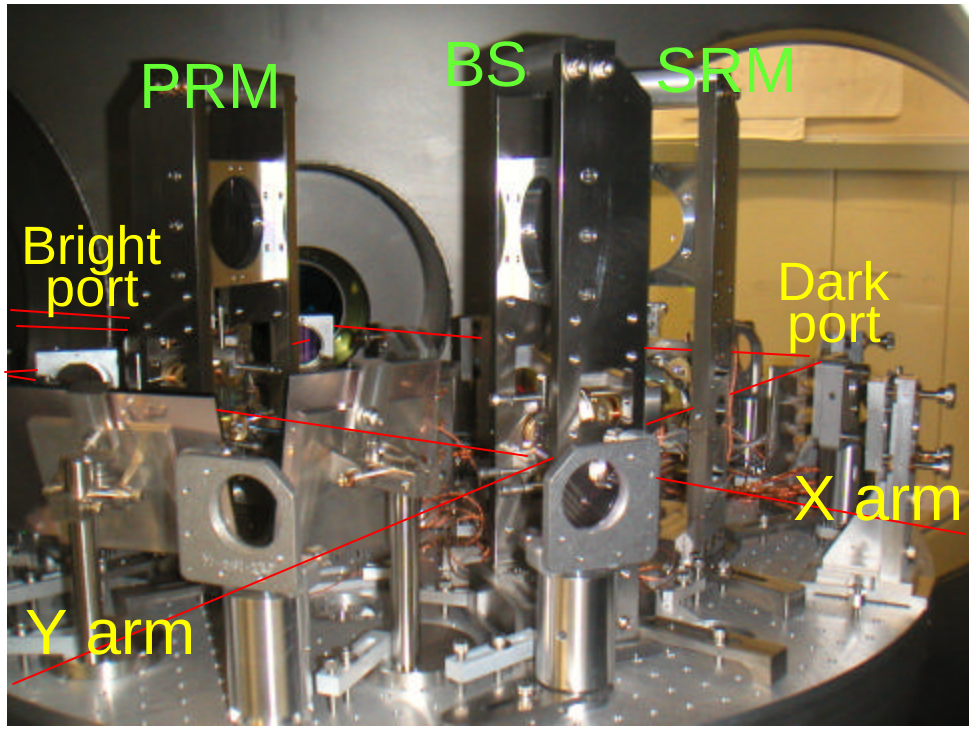
- Displacement spectrum obtained
- With all the whitening/de-whitening filters (2 of 4 orders) ON
- No feedback to laser frequency
- 2 months noise hunting
- Noise is limited by electronic noise of de-whitening filter and frequency noise.

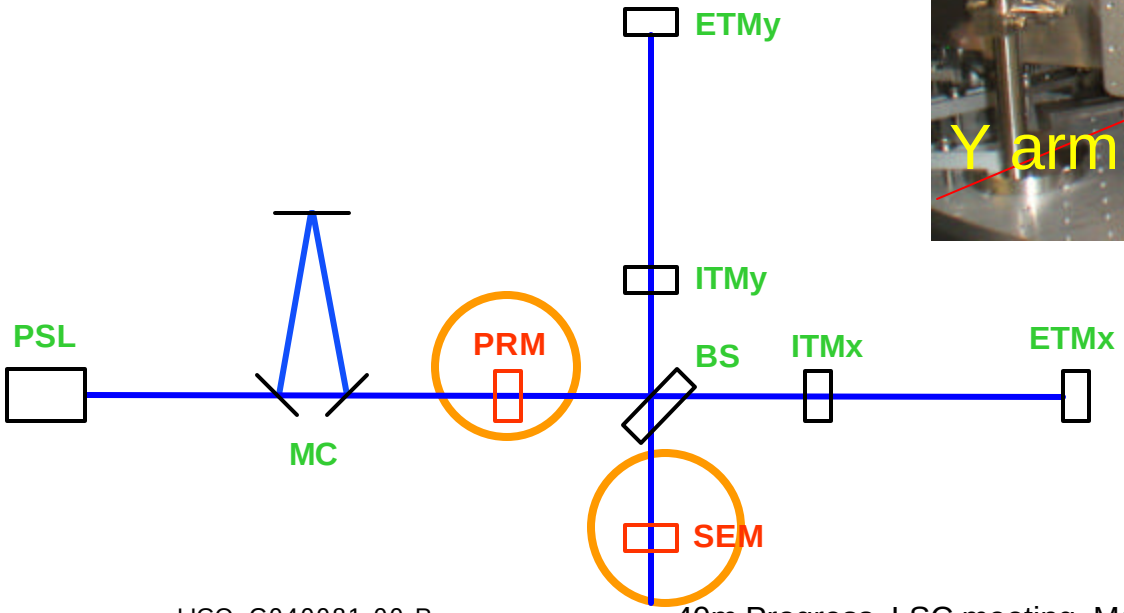


Important Achievement (4)
Installation of PRM and SRM

February 2004

- Power Recycling Mirror (PRM) , Signal Recycling Mirror (SRM) installed
- FPMI re-locked after installation

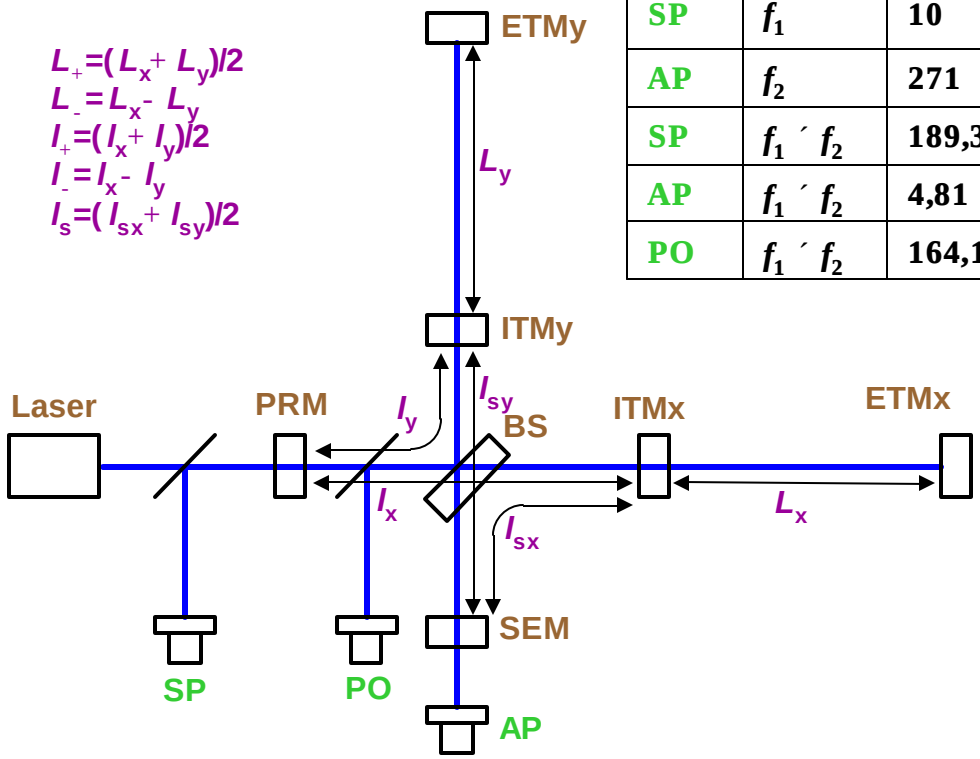




Other Achievements

- Simple and reliable calibration for PSL frequency noise
- Mode matching
  - » ~ 1% tolerance
- Estimation of loss on mirror
  - » ~ 90ppm (design 35ppm)
- Optical lever
  - » Helped the installation of PRM and SRM
- Input matrix of suspension
- Third Pockel's-cell for 166MHz modulation
- Two peak photo detector (133MHz, 199MHz) for double demodulation
- Replacement of NPRO and re-alignment of power amplifier
  - » Total power ~12.5W

Signal Extraction Matrix



Port	Dem. Freq.	Dem. Phase	L_+	L_-	l_+	l_-	l_s
SP	f_1	10	1	-3.8E-9	-1.2E-3	-1.3E-6	-2.3E-6
AP	f_2	271	-4.8E-9	1	1.2E-8	1.3E-3	-1.7E-8
SP	f_1 ´ f_2	189,32	-1.7E-3	-3.0E-4	1	-3.2E-2	-1.0E-1
AP	f_1 ´ f_2	4,81	-6.2E-4	1.5E-3	7.5E-1	1	7.1E-2
PO	f_1 ´ f_2	164,12	3.6E-3	2.7E-3	4.6E-1	-2.3E-2	1

- Calculated by FINESSE
  (A. Freise: http://www.rzg.mpg.de/~adf/)
- PO: light from BS to ITMy

Length Tolerances

- Acceptable cavity length deviations from the ideal points:
  - 6 cm for l_-
  - 3 mm for l_+
  - 3 mm for l_s

Example: Signal matrix with l_+ deviation of 1 cm

Port	Dem. Freq.	Dem. Phase	L_+	L_-	l_+	l_-	l_s
SP	f_1	334	1	-7.6E-9	-1.2E-3	-4.1E-6	-2.3E-6
AP	f_2	230	-1.3E-9	1	3.0E-8	1.3E-3	-1.7E-8
SP	f_1 ´ f_2	162,73	-6.5E-4	3.5E-4	1	-5.6E-2	1.3E-1
AP	f_1 ´ f_2	173,218	1.5E-3	4.2E-4	-2.1	1	-2.4E-1
PO	f_1 ´ f_2	329,153	1.1E-3	2.7E-3	2.6	-1.6E-1	1

S. Kawamura, “Signal Extraction Matrix of the 40m Detuned RSE Prototype”, LIGO-T040010-00-R (2004)

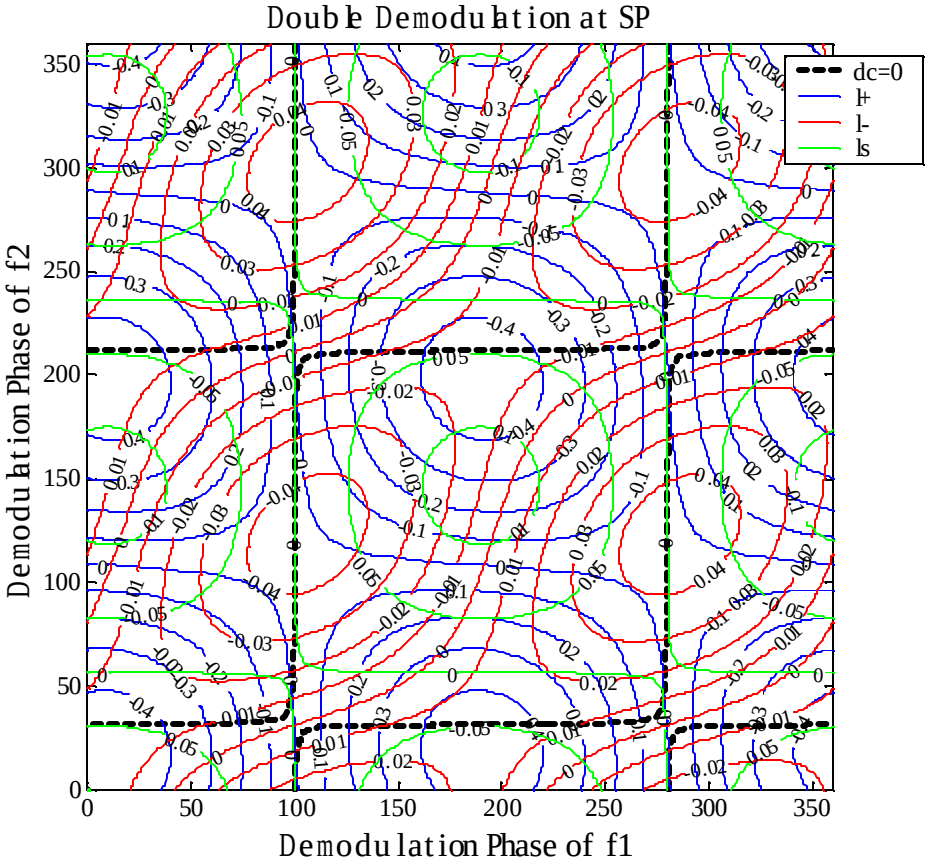
- Direct length measurement for PRC and SRC

  Error of the cavity length PR and SR ~ +/-1mm

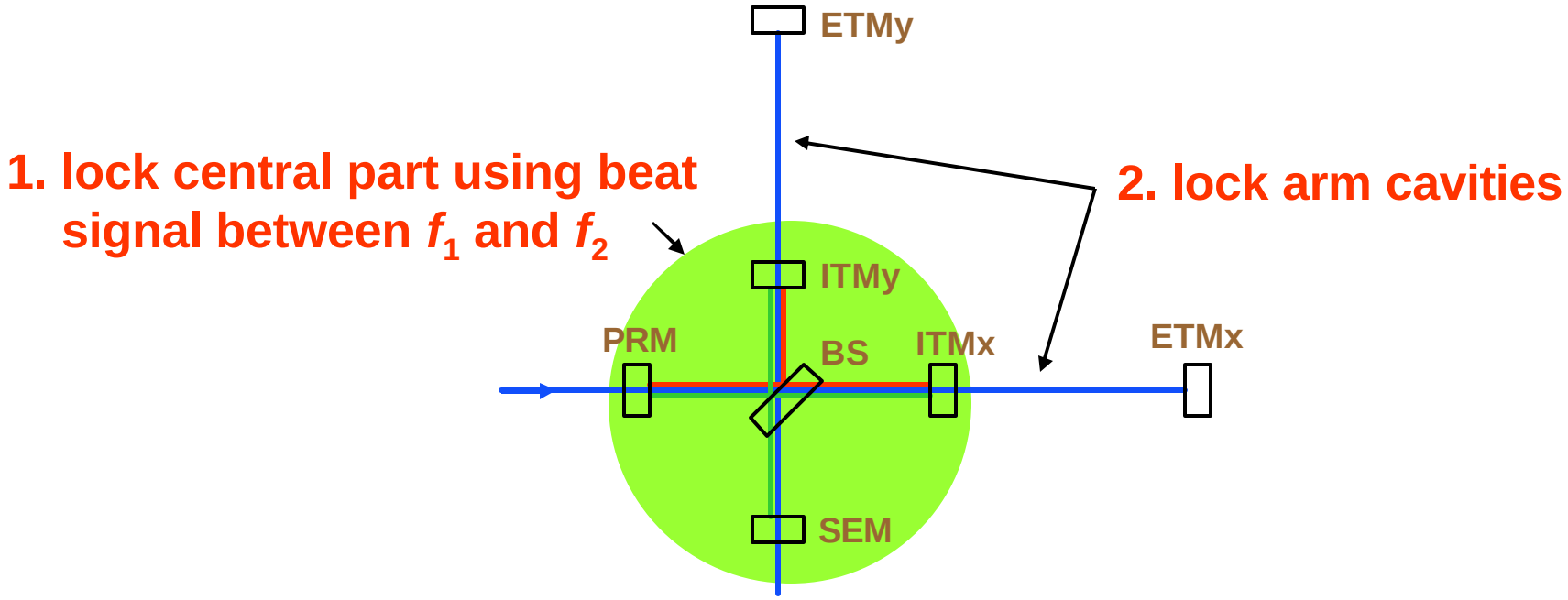
Double Demodulation

- Double Demodulation used for I_+, I_-, and I_s
- Demodulation phases optimized to suppress DC and to maximize desired signal

[S.Kawamura, "Signal Extraction Matrix of the 40m Detuned RSE Prototype", LIGO-T040010-00-R (2004)]



Lock Acquisition of Detuned RSE



- Central part: not disturbed by lock status change of arm cavity
- Question: Not disturbed by flash of SBs or SBs of SBs in arms?
- Promising: TAMA using 3rd harmonic demodulation in PRFPMI

Lock Acquisition of Central Part

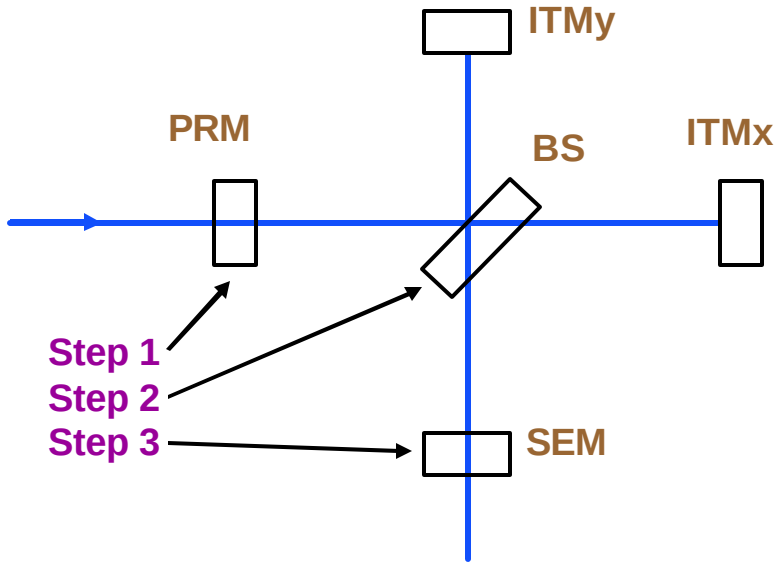
Ideal Procedure: Lock one by one

[for example]

Step 1: Lock l_+ robustly

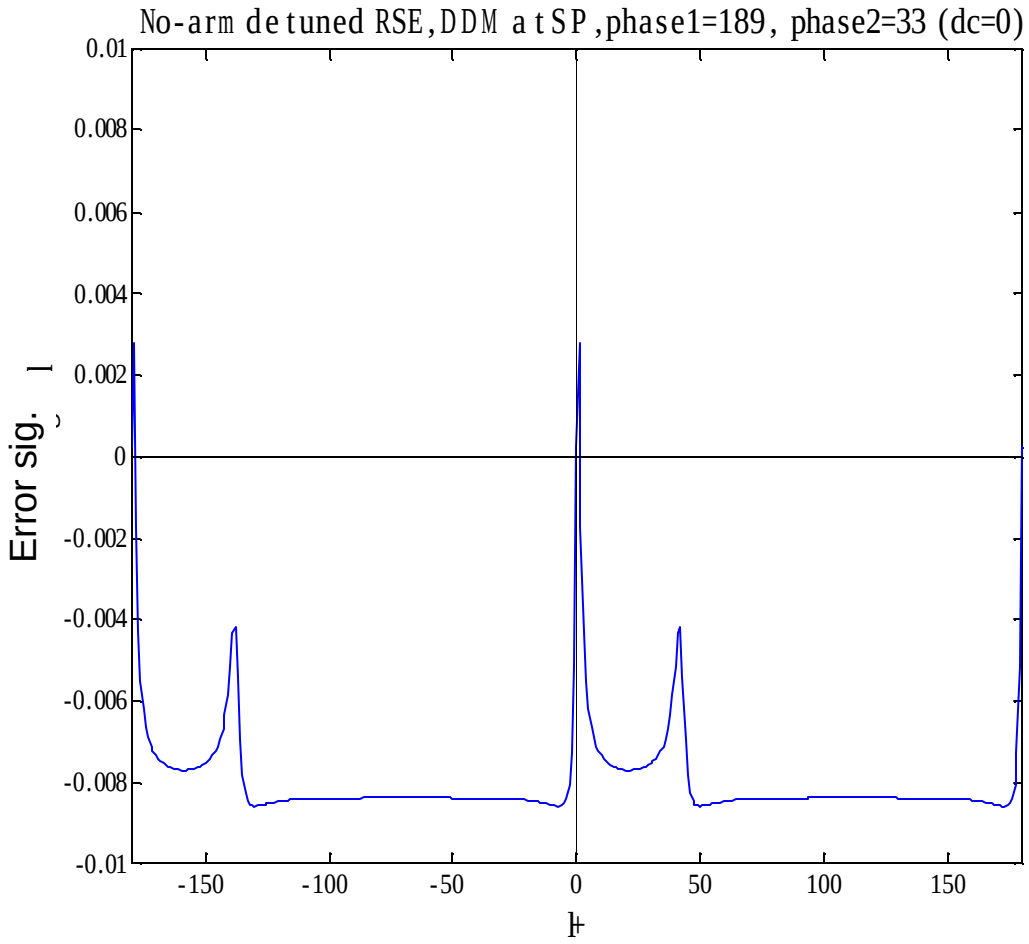
Step 2: Lock l_- robustly

Step 3: Lock l_s

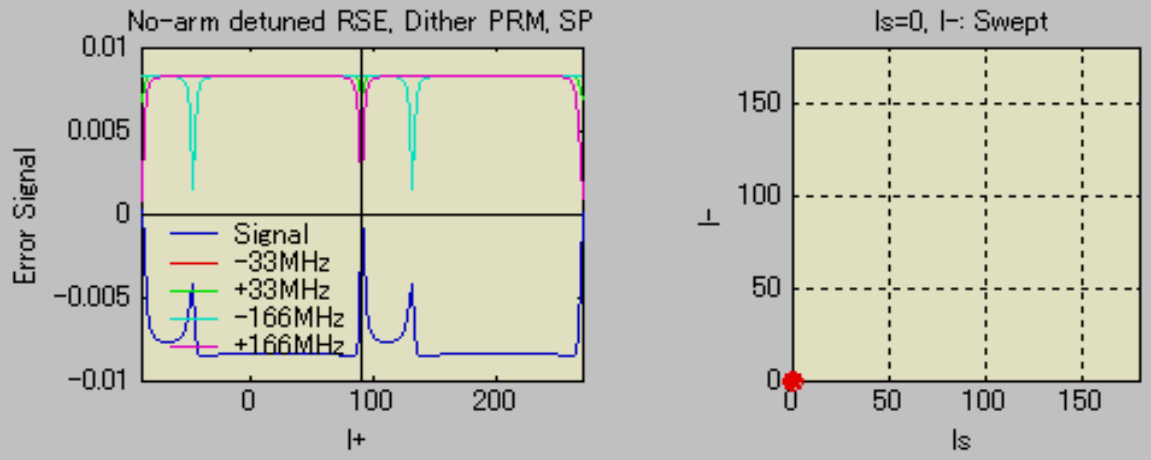


- Find primary signal not disturbed by the other two DOFs
- Find secondary signal not disturbed by the residual DOF

Quality of l+ Signal (dc=0, l+:Max)

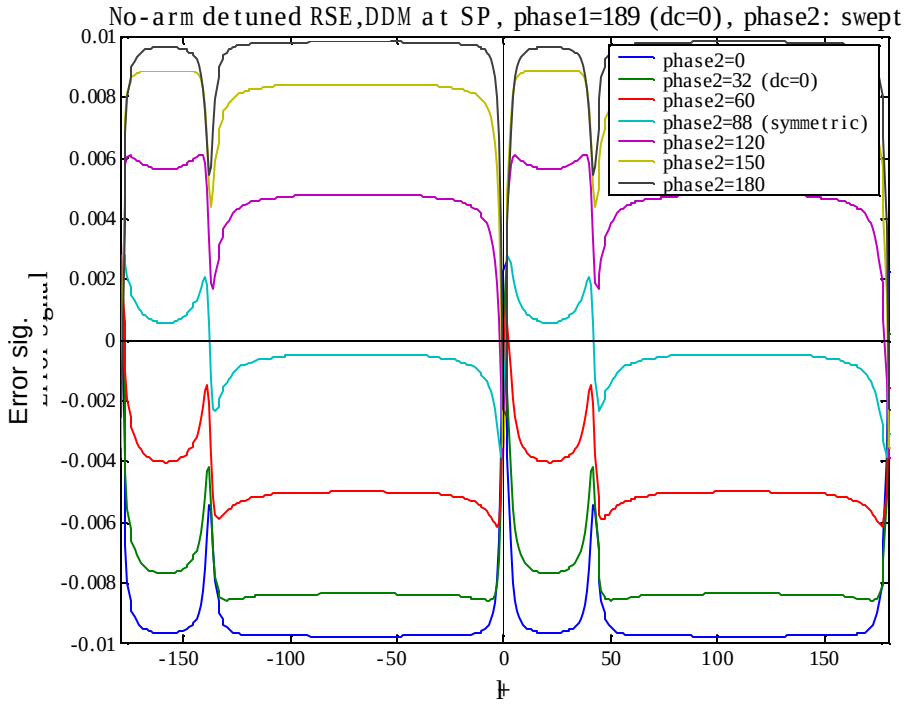


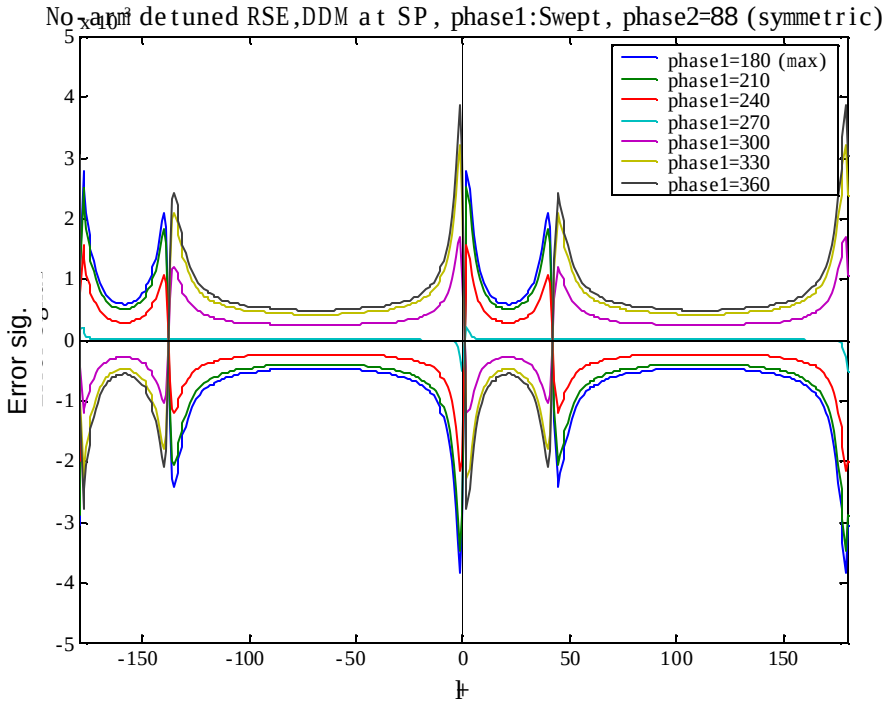
I+@SP, no offset



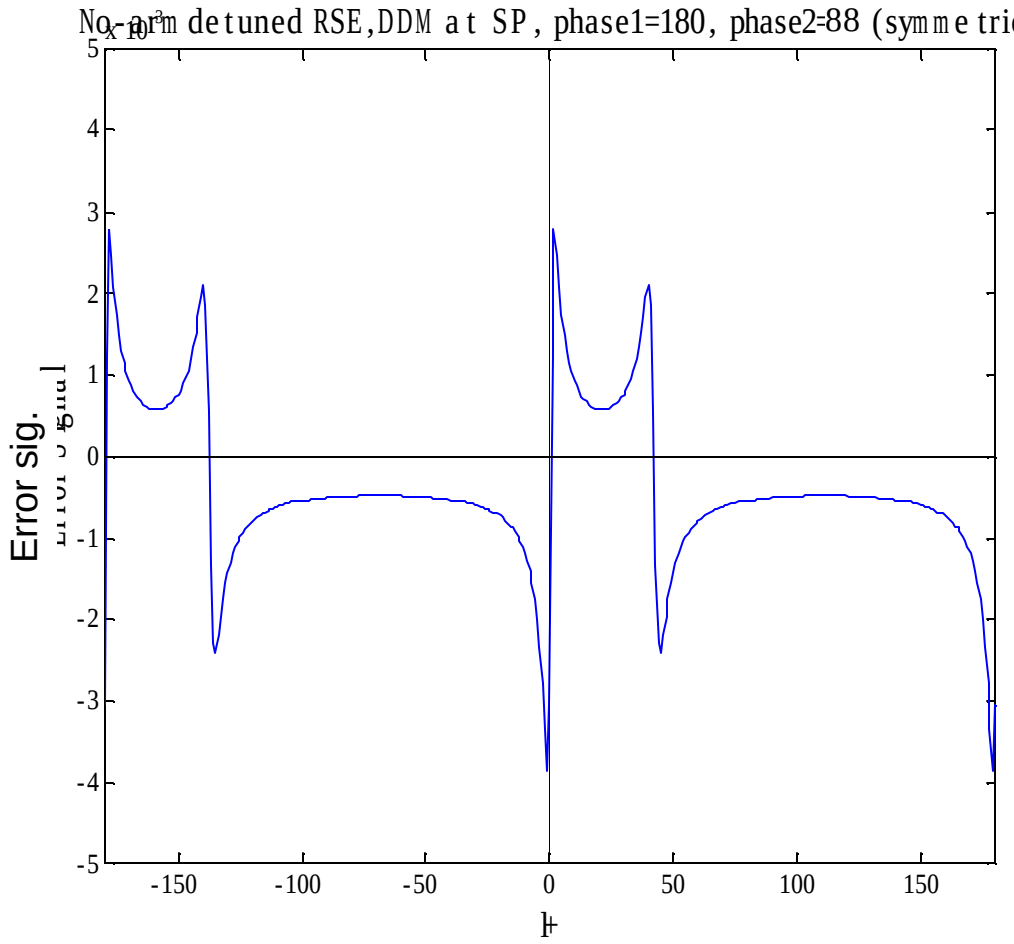
- Signals for ±f1 resonance appear

Dependence of l+ Signal on Demodulation Phases

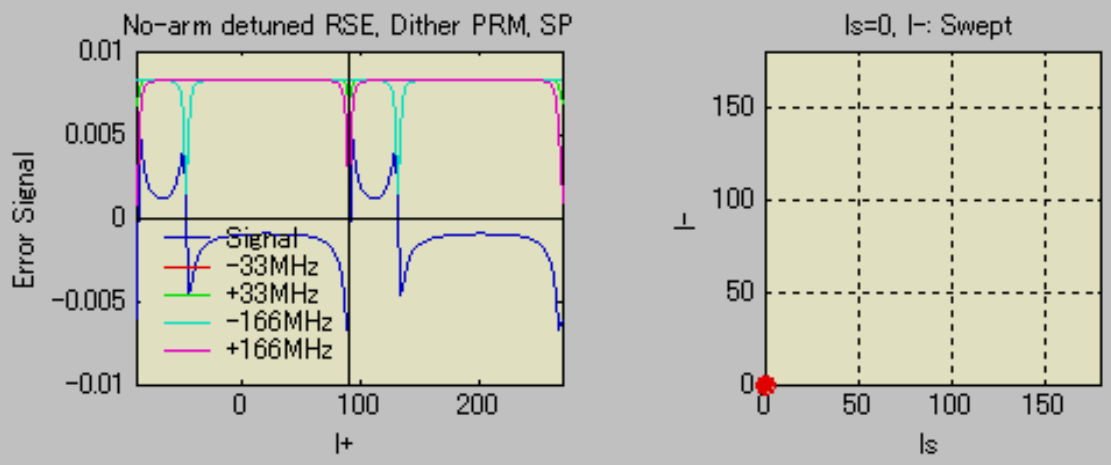




Quality of l+ Signal (Symmetric, dc≠0)

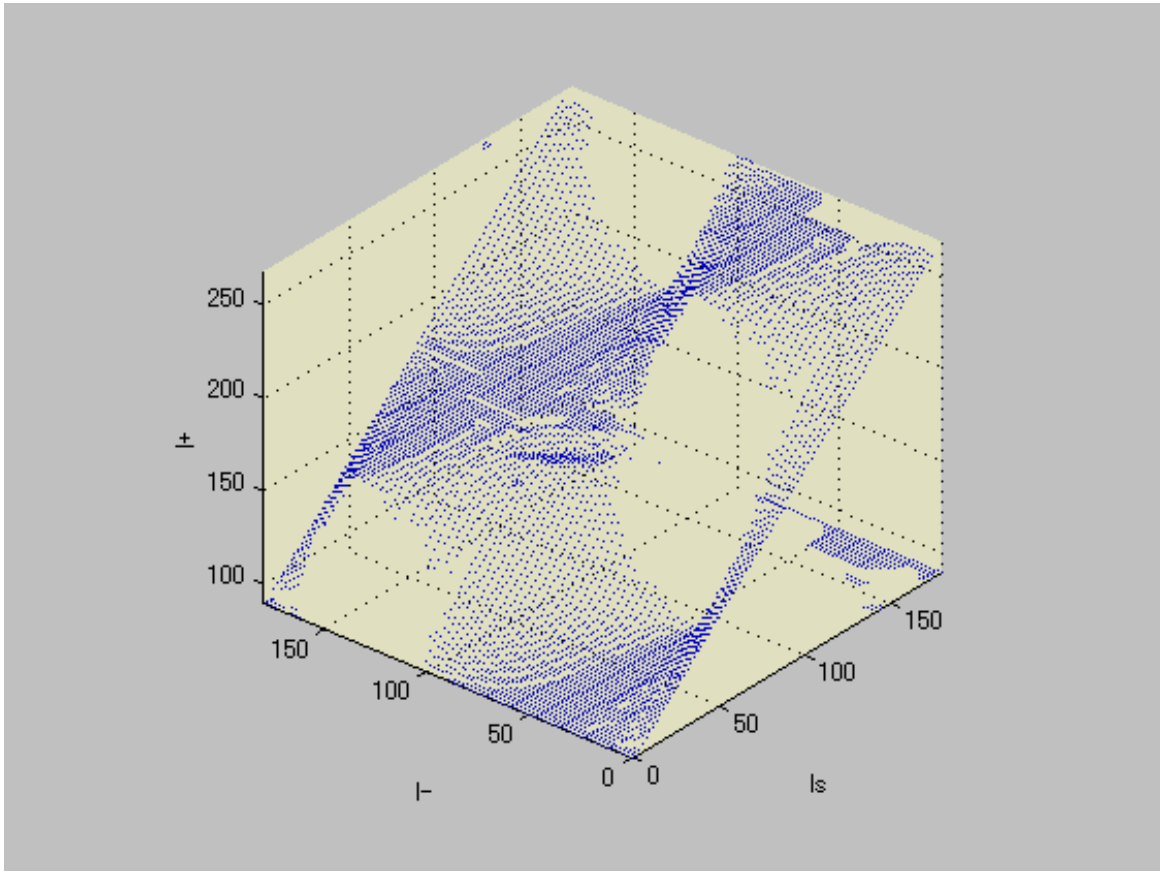


I+@SP, Symmetric



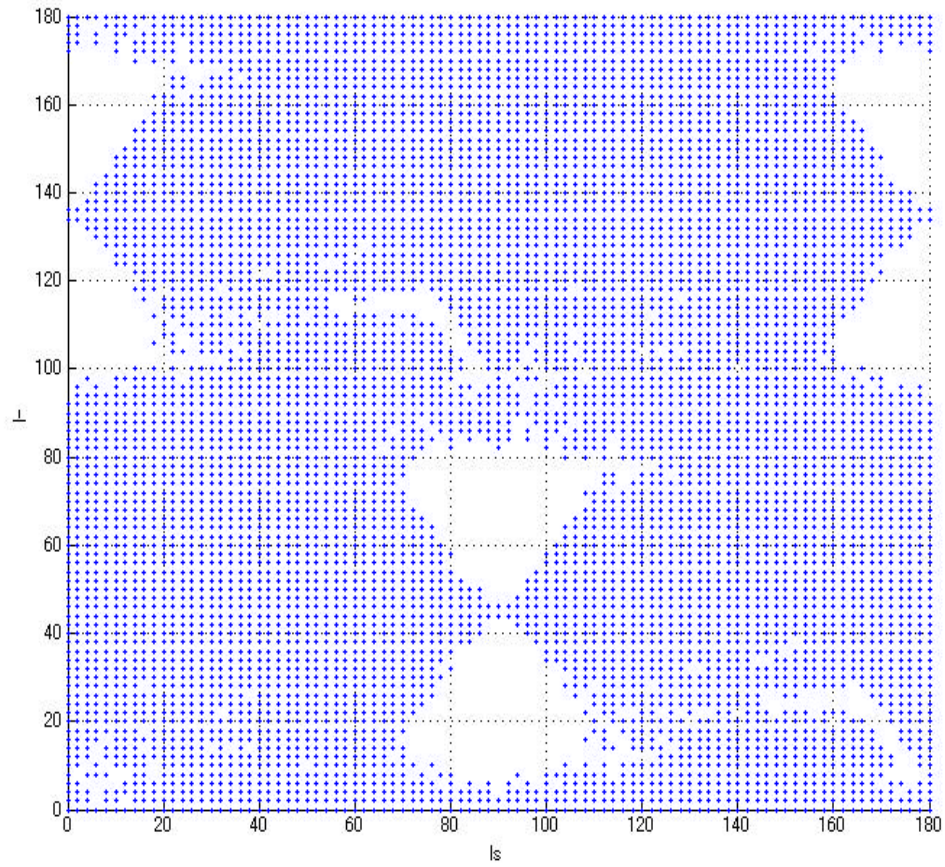
- Four SBs resonate at different points
- Good signal obtained when +f2 resonates
- Signal for –f2 resonance has an opposite polarity
- Disturbed when +f2 and –f2 resonate at the same point
- Signals for ±f1 resonance can be cancelled by proper DDM phases, which coincide with the phases for symmetric signal

I+ Signal lockable surface



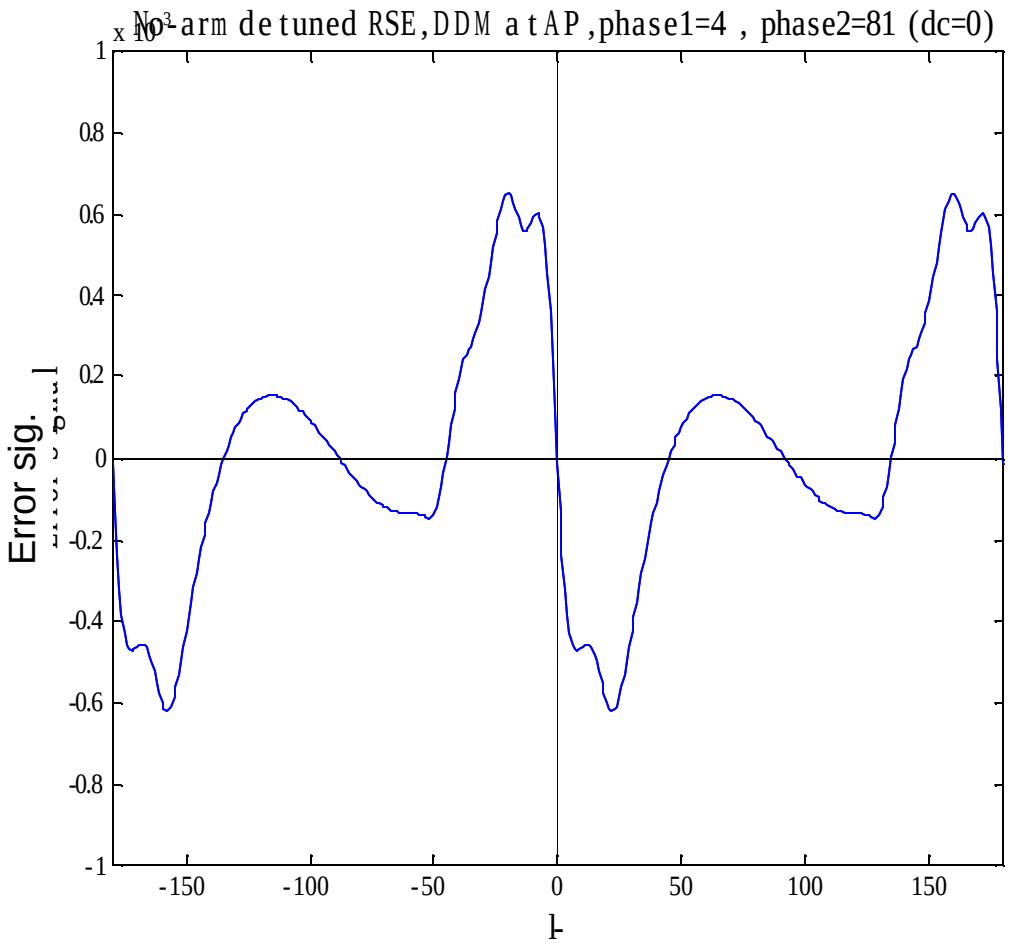
- I+ lock points makes one surface
- Gain change<3

I+ Signal lockable surface

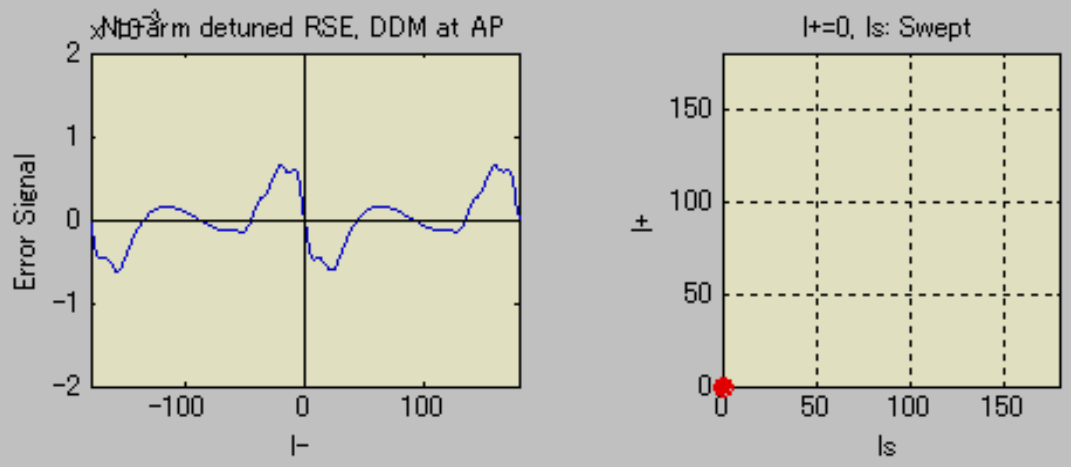


- Lock point surface covers pretty much (~80%) of all the I-, Is parameters
- Feedback I+ signal to laser frequency for fast locking (Feed around)

Quality of l- Signal



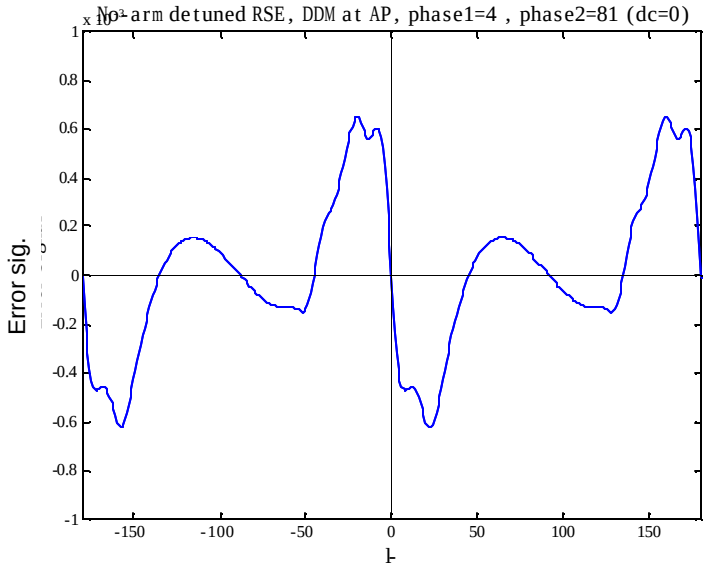
Dependence of l- Signal on ls



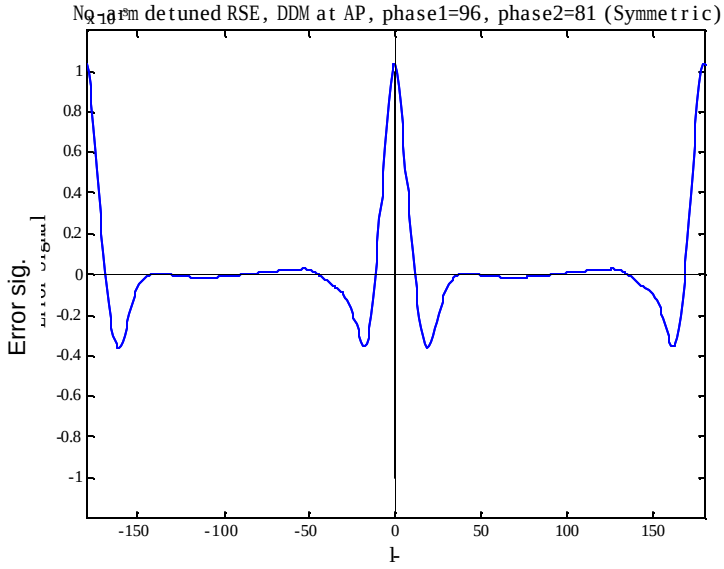
- No good signal obtained except for ls around resonant

I- Signal Divided by AP signal with different Dem. Phase

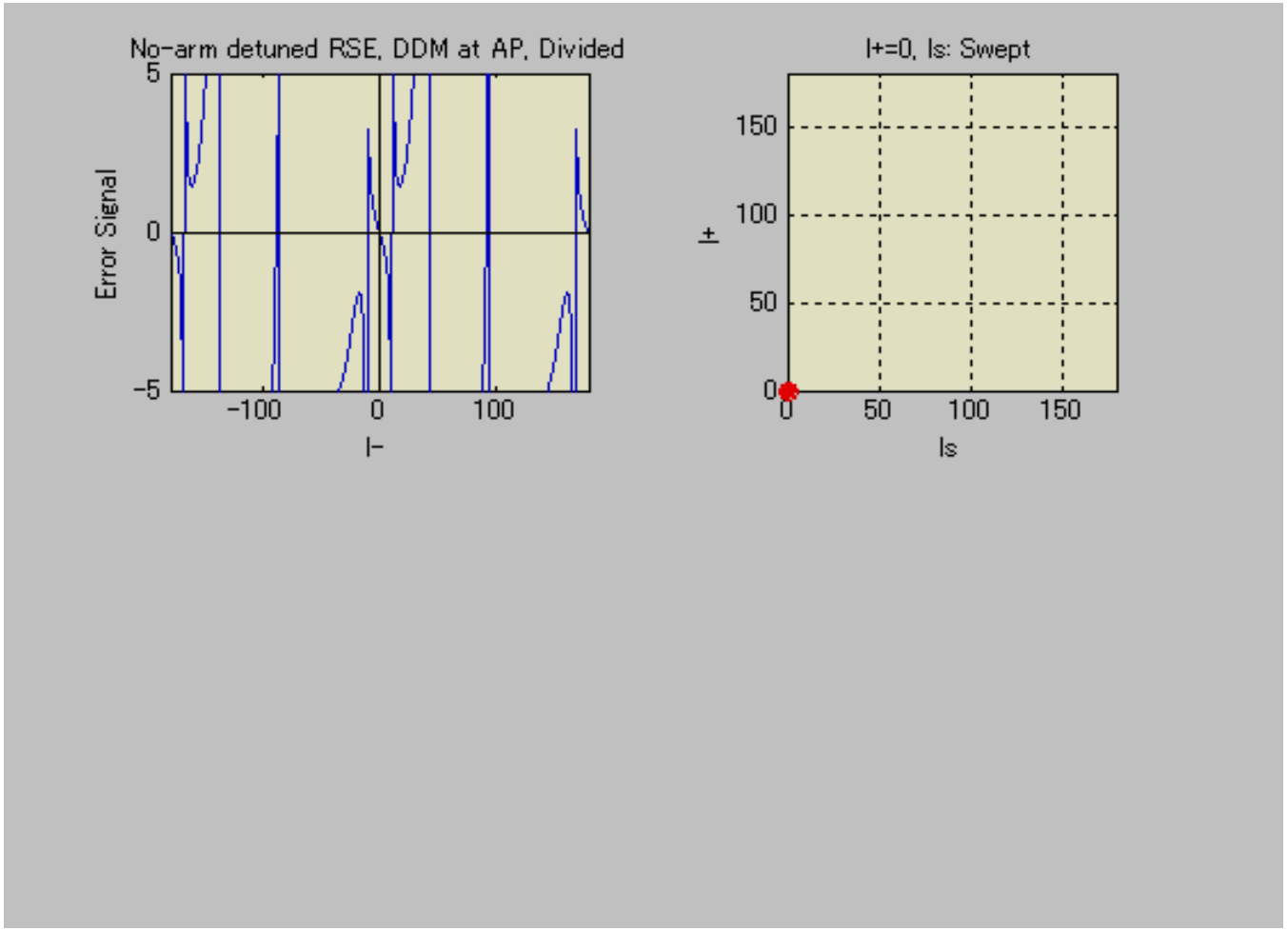
Hint: H. Grote at GEO



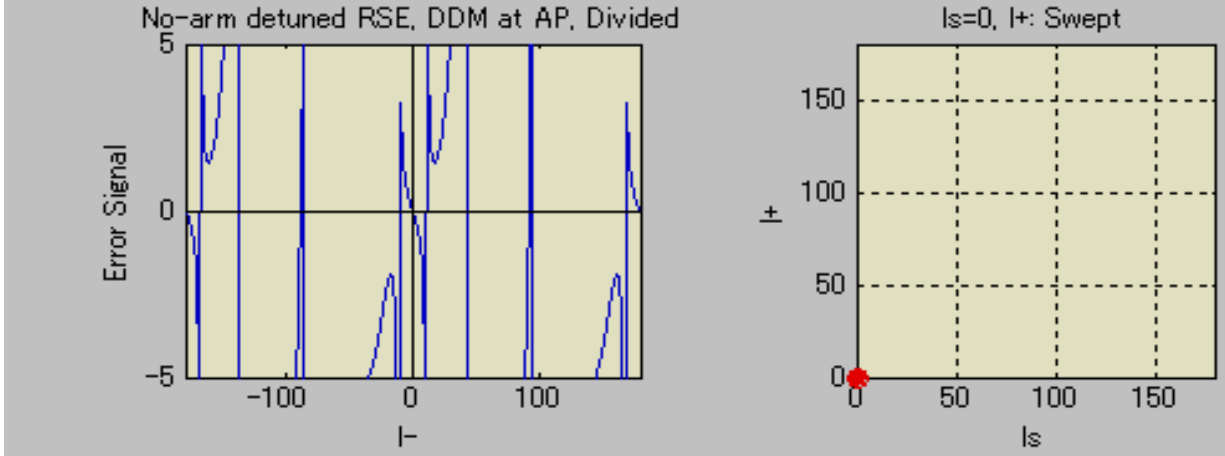
Divided by



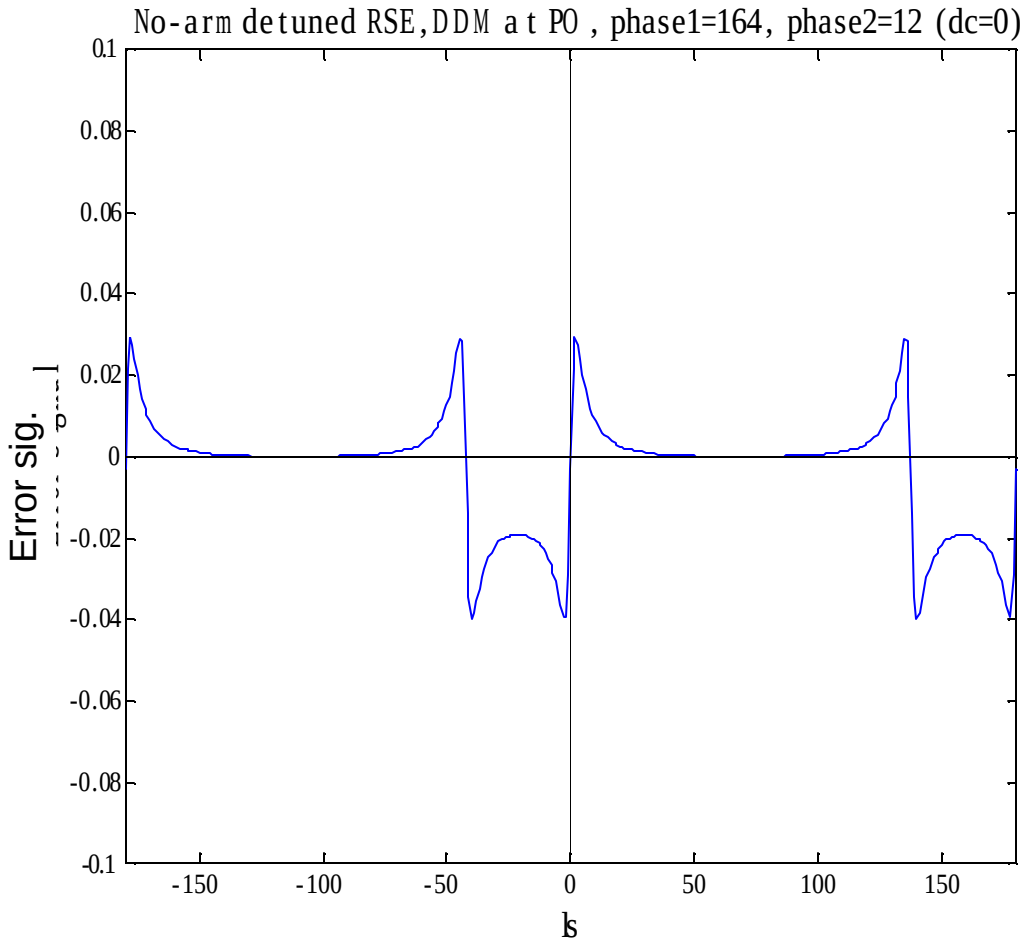
Dependence of Divided I- Signal on Is



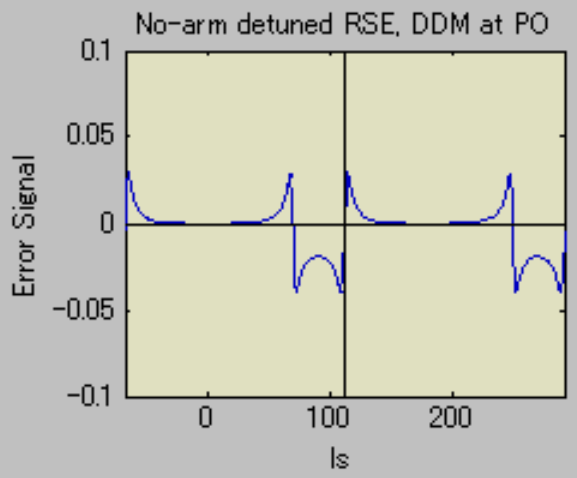
Dependence of Divided I- Signal on I+

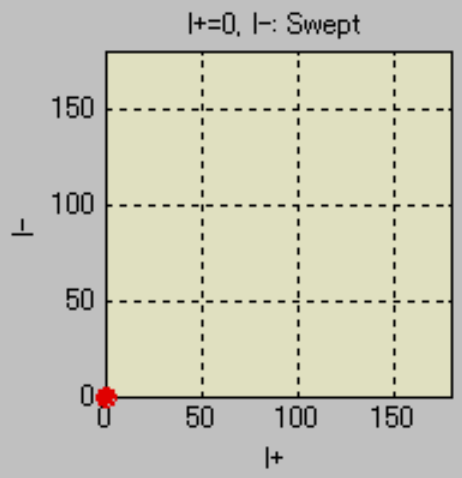


Quality of ls Signal



Dependence of ls Signal on l+





- No good signal obtained except for l+ around resonant

Looking for Good Signal …

Have tried many things, but not significant improvement…

- f1-dem, f2-dem
- Dither
- For l+:

  Single sideband f2, AM f2

  NR pm, am, single sideband f3:

  (f2-f3)-dem, (f1+f3)-dem

  On the surface of l+
- For l-, ls:

  Signal divided by the following:

  2×f1-dem, 2×f2-dem, DDM with different dem phases, (f2-2×f1)-dem

  On the surface of l+

Summary

- Lots of achievements; experiment on 40m going very fast and smoothly
- Almost ready to try lock acquisition
- Lock acquisition: not so easy
- Need more investigation for lock acquisition

Hope we succeed in locking detuned RSE very soon!