# Simulation Study for aLIGO Lock Acquisition


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## Abstract

There have been simulation effort to study the lock acquisition process that will be used in the Advanced LIGO interferometers. Lock acquisition requires complicated signal processing because the length degrees of freedom are not in the vicinity of the operating point and therefore the signals are highly nonlinear. The study was focused on searching for a good combination of the signals and its feasibility test in time domain. In this poster, we present a plausible combination of the signals and possible sequence with the use of arm length stabilization.


## 1. Background

Lock acquisition is not straightforward because of:

√ cross-coupling in the length signals
√ nonlinearity in the length signals

Moreover the sensing matrix dynamically evolves as the cavities are brought into the operating point.
**Therefore we need a tractable procedure.**

## 2. Two key techniques

**√ Strategy in aLIGO:**
Make the arms and central DRMI independent of each other to reduce the complexity in the signal sensing. To do so, we employ two key technologies:

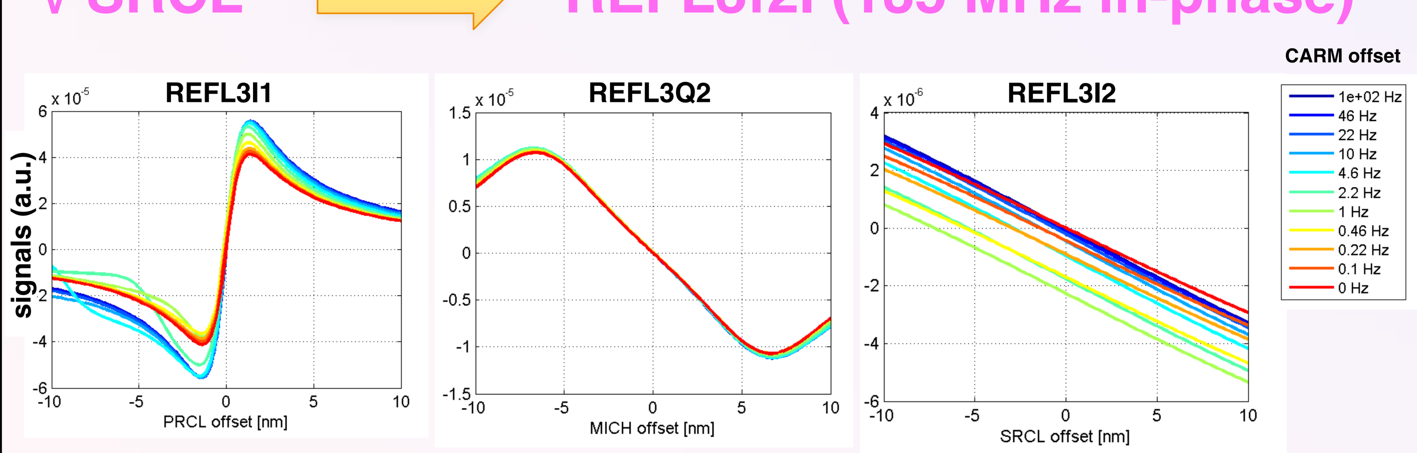
**1. Arm length stabilization (ALS)** [1,2]
With the use of an auxiliary laser on each arm, one can sense the arm cavities independent of the DRMI. The stability is sensor noise limited (~ 30 Hz or 430 pm RMS, measured at LHO).

**2. Third harmonic demodulation** [3]
**(aka 3f technique)**
Demodulating light at the third harmonic of a phase mod. frequency, one can extract signals that are less sensitive to the carrier light. Therefore they are less sensitive to the arms.

## 3. Steady state study

The 3f signals are carefully chosen such that they experience less variation in the optical gain and offset. This was studied by *Optickle* [4]

√ PRCL ⇒ REFL3f1I (27 MHz in-phase)
√ MICH ⇒ REFL3f2Q (135 MHz q-phase)
√ SRCL ⇒ REFL3f2I (135 MHz in-phase)



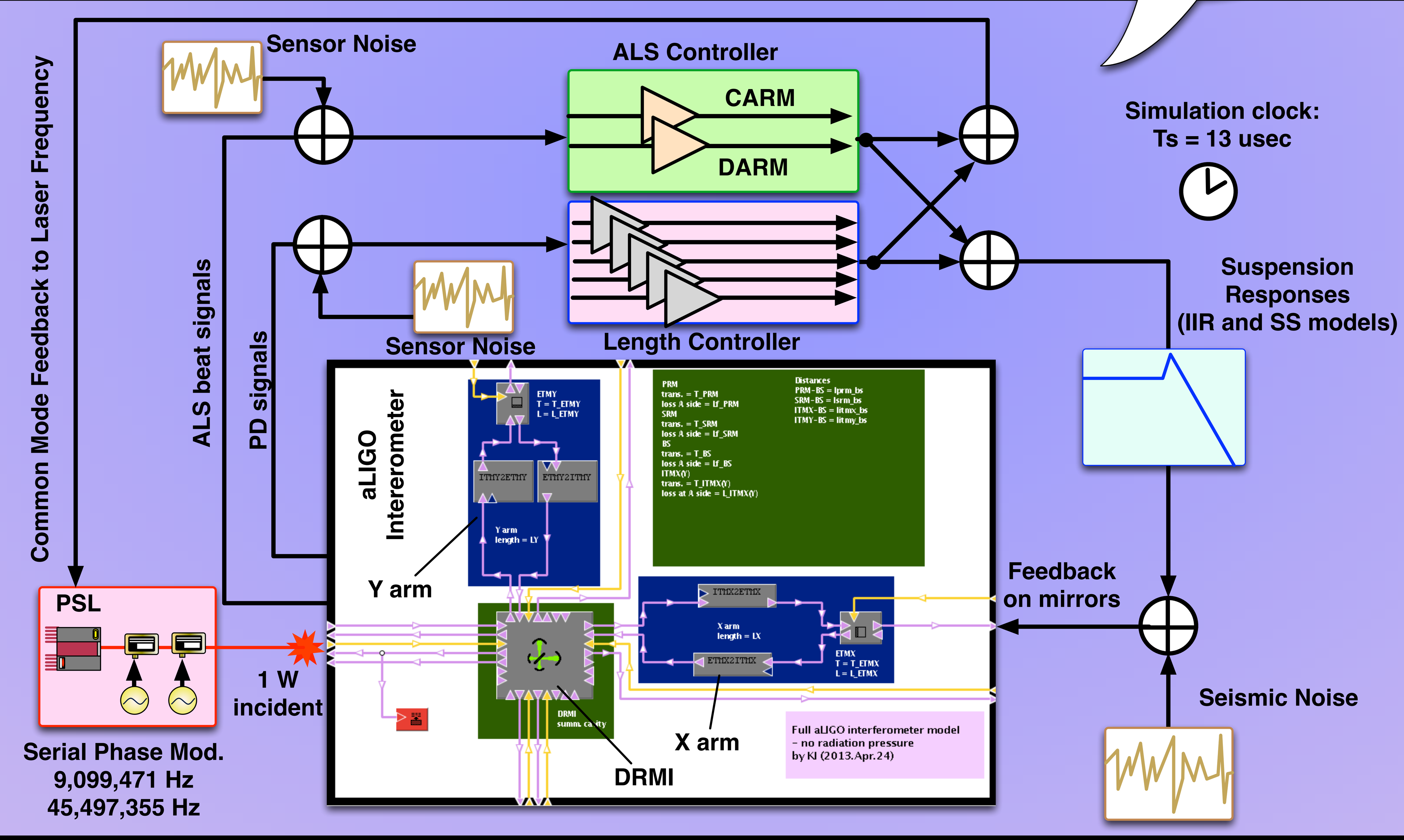

## 3.Time domain study

In order to test the combination of the signals and to figure out a possible procedure, a time domain simulation was performed. We used E2E [5] which is capable of simulating dynamical, nonlinear effects.

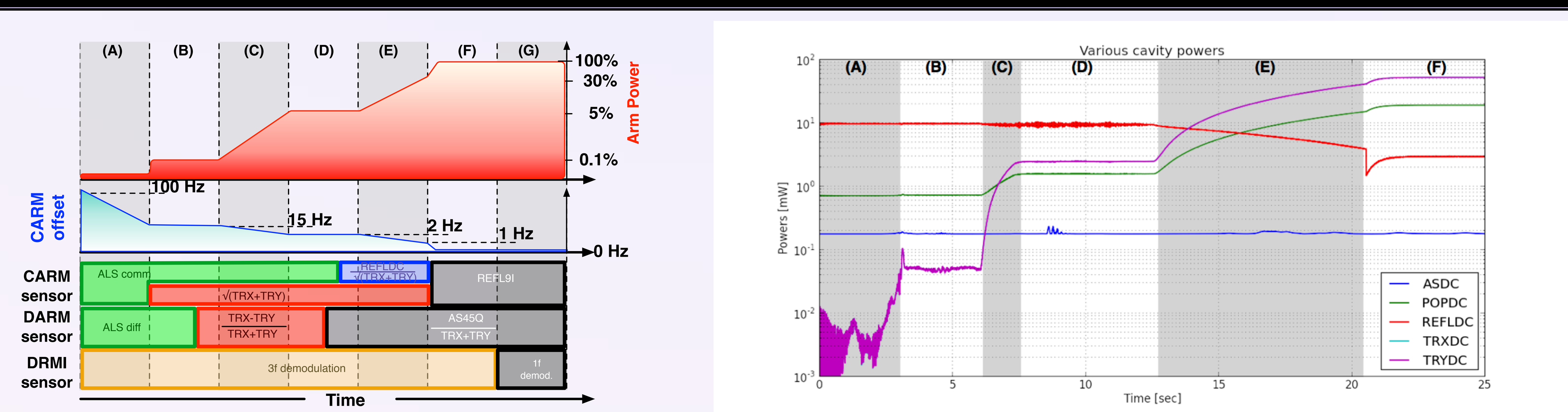
**Assumptions are:**

√ No radiation pressure is included
√ ETMs are the quadrupole suspensions
√ PRM, SRM and BS are HSTS (triple suspensions)
√ ALS is limited by sensing noise
√ No laser frequency noise is included
 * see [6] for more details.

**Simulation setup for the time domain study**



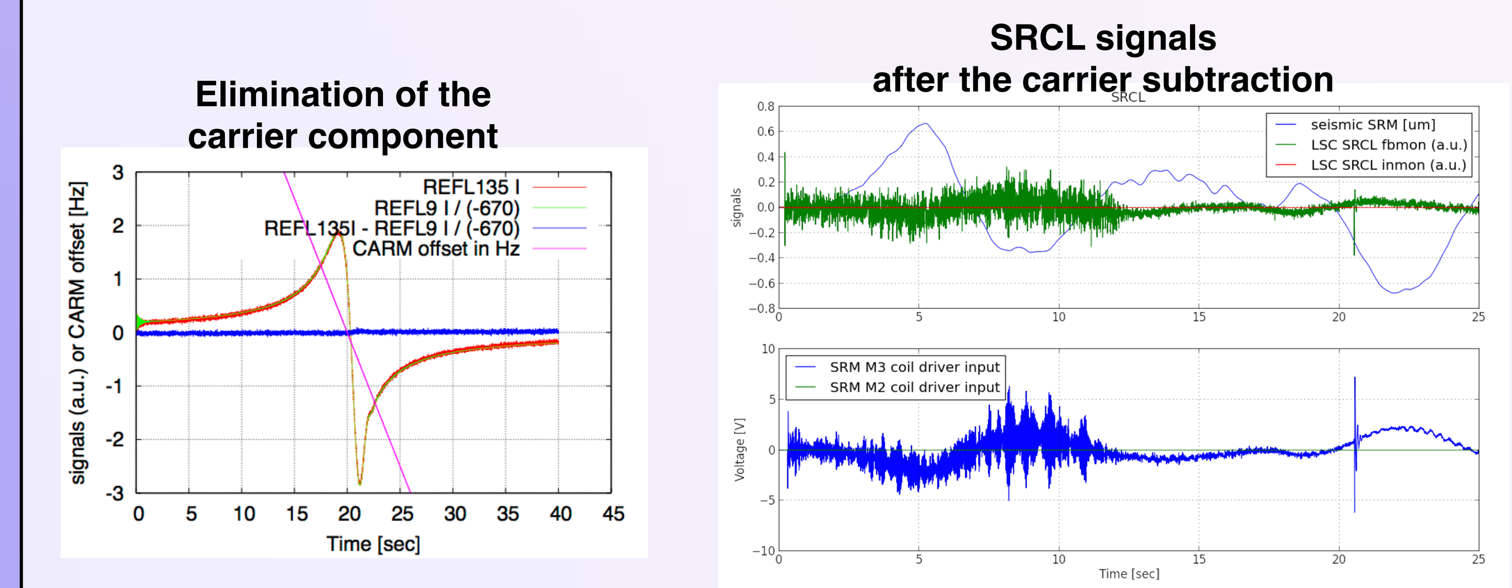

## 4. Simulation Results




We introduced an offset in CARM for locking DRMI. Then the offset was reduced while the sensors for DARM and CARM were sequentially switched in order to have higher signal-to-noise ratio.

## 5. Offset in SRCL

A carrier component in the 3f signal changes the offset in the SRCL error signal. This can potentially cause saturation in the SRM coil driver circuits. One way to mitigate this issue is to subtract the carrier component by adding a signal which is sensitive to the carrier.
e.g. REFL9I and REFL45.




## 6. Summary and future

**Summary:** A possible combination of the signals and procedure were tested in the time-domain interferometer simulator. We demonstrated that the interferometer can be fully locked. This study should aid in better understanding of the dynamical length sensing and control.

**What will be happening?:** Currently LIGO Livingston is in a phase where they can test out the proposed combination of the signals and procedure. With the aid from the simulation works, we will soon figure out a robust locking sequence.

**Check this out:** alternatively there is a new dramatic way of locking the common mode of the interferometer [7].


**Acknowledgement**

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**References**


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[4] Optickle, http://optickle.github.io
[5] E2E, http://www.ligo.caltech.edu/~e2e/
[6] KI, et al "Simulation study for aLIGO lock acquisition", LIGO-DCC-T1400298-v1
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LIGO-G1400560-v2