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Possible sets of lengths and modulation frequencies for Advanced Virgo

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1 Introduction

This note explores several different sets of lengths and modulations that can be used for the longitudinal sensing and control of Advanced Virgo. The proposed scheme for the lock acquisition is the same already explained in the previous note [2]:

- the signal recycling mirror (SRM) is initially largely tilted in order to avoid its reflection to re-enter the interferometer;
- in this way the interferometer is in a Virgo-like configuration and it can be brought to dark fringe with a straightforward extension of the Virgo variable finesse technique [6];
- the Schnupp asymmetry and modulations must be chosen in such a way to have one pair of sidebands (SB1) almost not transmitted to the anti-symmetric port (ASY): these are the sidebands to be used for controlling the Virgo-like degrees of freedom (MICH, PRCL, CARM, DARM); the perturbation to the carrier and SB1 fields inside the power-recycling cavity (PRC) when the SRM is re-aligned and the SRC crosses a resonance must be small; in this way the SRC can be locked without disturbing the rest of the ITF control;
- a second pair of sidebands (SB2) must be significantly transmitted to ASY and be resonant in the signal recycling cavity (SRC) to give a signal sensitive to this length (SRCL);
- finally a third pair of sidebands (SB3) should be anti-resonant in the PRC, being completely reflected by the interferometer; this pair can be useful to extract control signals for frequency stabilization and for the central part d.o.f.s.

The choice of lengths and modulation frequency can be split in three main parts:

- selection of the basic modulation frequency to be resonant inside PRC and anti-resonant in the arms: this gives relations between the IMC length, the PRC length and the main modulation frequency;
- selection of the Schnupp asymmetry: this tells which multiples of the basic modulation must be used;
- selection of the SRC length and of the second modulation frequency: this is particularly critical since it might imply a large change in the signal recycling tower position.

Note: all the length computed here refers to the optical distances between the high reflection coated surfaces of the mirrors. The real physical distances between the mirror suspension points must be computed accordingly taking into account the mirror thickness and refraction index.

2 Basic modulation frequency and PRC length

As already explained in the previous note [2], the requirements that the basic modulation frequency must be transmitted by the input mode cleaner and resonant inside the power recycling cavity fix a value close to 6.24 MHz for a 12 m long PRC cavity. This frequency must be chosen to be anti-resonant in the arm cavities. However, if it is perfectly anti-resonant, the second harmonic will be resonant. To avoid this problem, a small detuning can be added: this does not affect significantly the anti-resonance, given the very high finesse of the cavities, but can easily bring the higher harmonics out of resonance. The resonance width of the Advanced Virgo cavity will be of the order of 30 Hz with a finesse of about 880. Therefore a detuning of 50 Hz is enough to place the second harmonic at three times the peak width away from resonance.

Given a cavity length $L_{CAV} = 3000.0812$ as reported in [4], the basic modulation frequency is

$$f_0 = 6.27043919 \text{ MHz} \tag{2.1}$$

and the corresponding optimal lengths for IMC and PRC are:

$$L_{IMC} = 143.431 \text{ m } (143.573 \text{ m }) \tag{2.2}$$
$$L_{PRC} = 11.953 \text{ m } (12.053 \text{ m }) \tag{2.3}$$

The values between brackets are the ones measured for Virgo [4].

3 Schnupp asymmetry

The baseline for Advanced Virgo will use DC detection [7]. For this reason there is no need of having large sidebands transmitted to ASY in order to extract the gravitational signal. Therefore there is more freedom to choose the modulation frequency and Schnupp asymmetry more suitable for the longitudinal sensing and control. As explained in the introduction, SB1 must be almost not transmitted to ASY: in this way the interferometer reflectivity for SB1 entering from ASY will be close to 1 and the perturbation to the SB1 fields inside the PRC can be made small, even with a sweeping signal recycling cavity.

The two critical parameters to choose f_1 and f_2 are

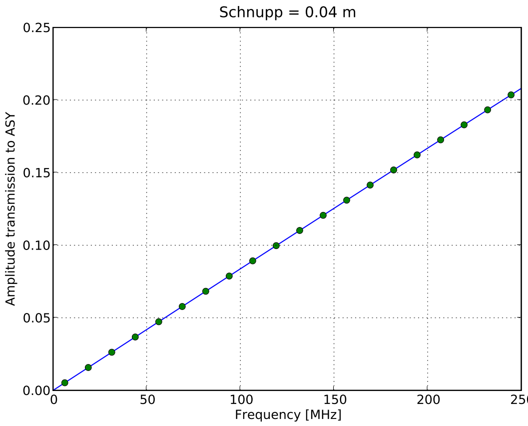
- the transmission to ASY, which is defined as the amplitude ratio between the field in ASY and inside the power recycling cavity;
- the back coupling, defined as the relative perturbation of the sideband field inside the PRC when the SRC crosses a resonance, see sec. 6.4 of [2].

The modulation frequency for SB1 must be chosen in order to have small transmission to ASY. This can be accomplished with two different options: a small Schnupp asymmetry can be chosen, as already explained in [2], or a large asymmetry tuned with a given modulation frequency.

3.1 Small Schnupp asymmetry option

As explained in [2], a small Schnupp asymmetry will give a small transmission of the 6 MHz sidebands. Choosing a high enough frequency for SB2 will ensure enough transmission to control SRCL (see fig. 1). Here an asymmetry of 4 cm is proposed, which correspond to the lengths and modulation frequencies listed in tab. 1:

The transmission of SB1 to the signal recycling cavity depends almost linearly with the Schnupp asymmetry. Therefore to maintain a small perturbation from SRC to the main ITF the Schnupp asymmetry is required to be not larger than 5-6 cm. However, if it is too small, the transmission of SB2 will be affected and the SRC error signal might suffer from this.



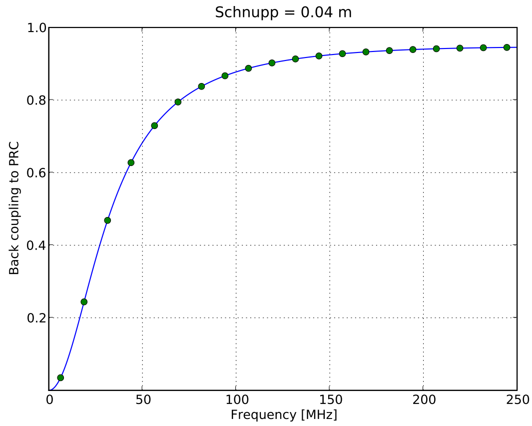


Figure 1: **Left**. Amplitude transmission of sideband field from PRC to SRC for a small Schnupp asymmetry, as a function of the modulation frequency. Dots mark the frequencies resonant inside the PRC. **Right**. Back coupling of sideband field inside the PRC when the SRC crosses a resonance.

Length	**Symbol**	**Value**	**Virgo value**	**Difference**
PRC length	L_{PRC}	11.953 m	12.053 m	-0.100 m
IMC length	L_{IMC}	143.431 m	143.573 m	-0.142 m
Schnupp asymmetry	Δ	0.04 m	0.878 m	-0.838 m
Distance BS-PRM	l_P	5.980 m	5.980 m	+0.000 m
Distance BS-IMX	l_N	5.993 m	6.512 m	-0.519 m
Distance BS-IMY	l_W	5.953 m	5.634 m	+0.319 m
SB1 modulation	f_1	6270389.2 Hz		
SB3 modulation	f_2	8360585.6 Hz		

Table 1: . Lengths and modulations for the small Schnupp asymmetry option.

In general the advantage of this choice is that a very precise tuning of the Schnupp asymmetry is not needed and that the Virgo-like degrees of freedom will be controlled with a frequency close to the one used for Virgo and Virgo+.

The choice of the second modulation depends strongly on the length of the SRC, and it will be addressed in a later section. The third modulation should be chosen to be anti-resonant in the PRC and small enough not to be significantly transmitted to ASY. The best choice would be the second harmonic of the basis frequency. Since we added a small offset from anti-resonance to the basis modulation, this frequency will be slightly detuned from resonance. However it might be safer to move further away from the cavity resonance. It is possible to add offsets in multiples of the IMC free spectral range, for example:

$$f_3 = 2f_1 - 4 \times \frac{c}{2L_{IMC}} = 8360585.6 \text{ MHz} \tag{3.1}$$

Clearly the smallest this frequency is, the less it is transmitted to the signal recycling cavity.

3.2 Large Schnupp asymmetry option

For a large Schnupp asymmetry, the sideband resonant conditions inside the power recycling cavity changes when

$$\cos\left(\frac{\Omega\Delta}{c}\right) < 0$$

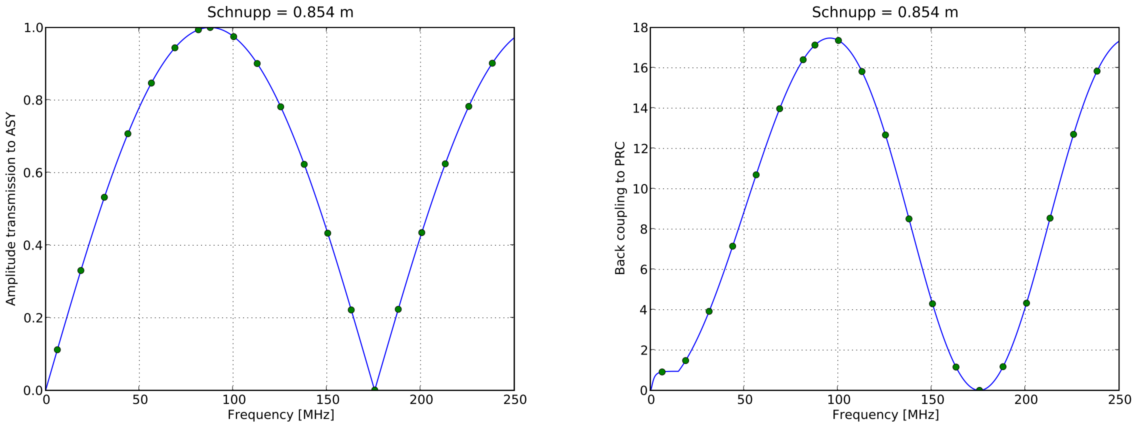


Figure 2: **Left**. Amplitude transmission of sideband field from PRC to SRC for a large Schnupp asymmetry, as a function of the modulation frequency. Dots mark the frequencies resonant inside the PRC. **Right**. Back coupling of sideband field inside the PRC when the SRC crosses a resonance.

which for a Schnupp asymmetry close to the Virgo value ($\Delta = 0.878$ m [4]) happens around 85 MHz. For smaller modulation frequencies the resonance condition is still $f = (2N+1) \times \frac{c}{4l_{PRC}}$, while for larger one it becomes $f = 2N \times \frac{c}{4l_{PRC}}$. This implies that larger frequencies will be close to cavity resonance. This can be avoided by a retuning of the power recycling cavity length which can exchange the role: lower frequencies will be close to resonance and higher ones to anti-resonance. The IMC length must be accordingly re-tuned.

If a large Schnupp asymmetry is used the SB1 modulation frequency must be chosen to match the first zero of the field transmission to ASY, see fig. 2. Since the frequency is fixed by the resonance conditions of IMC and PRC, a small tuning of Δ is needed to obtain this condition. Indeed the first zero of the ASY transmission is close to 170 MHz. The closest possible modulation frequency is $f_1 = 175572247.4$ Hz and the optimal Schnupp asymmetry is 0.854 m, see fig. 3. This frequency is however quite close to the arm cavity resonance, due to the flipping resonance condition inside the PRC. It is however easy to slightly change the PRC and IMC length in order to move this frequency to an anti-resonance of the cavity:

$$\begin{aligned} L_{IMC} &= 143.451 \text{ m} \\ L_{PRC} &= 11.954 \text{ m} \\ f_1 &= 175548765.3 \text{ Hz} \end{aligned}$$

Choosing the optimal Schnupp asymmetry can reduce the transmission of SB1 to the SRC very close to zero. Indeed for a length between 0.851 and 0.856 m the amplitude transmission from PRC to SRC is lower than 1%. The back-coupling can be reduced below 1% by choosing a Δ between 0.848 and 0.859, or below 0.1% with Δ between 0.852 and 0.856. Therefore with a tuning of the Schnupp asymmetry within 0.3 cm from the optimal value the back-coupling can be reduced to a negligible level.

The choice of the second modulation f_2 can be made accordingly to the SRC resonance condition, since any frequency far enough from f_1 is significantly transmitted to SRC cavity.

Instead the choice of the third modulation might be slightly more critical. Indeed the 8 MHz one satisfies the requirement of not being resonant in the PRC cavity, but its transmission from PRC to SRC is quite large (about 20%) and the back coupling is close to 1: this might result in a larger coupling of SRC length change to signals extracted from f_3. A better solution is the choice of f_3 close to f_1, spaced only by half PRC free spectral range plus a free spectral range of the IMC to move it further away from the cavity resonance:

$$f_3 = f_1 - \frac{c}{4L_{PRC}} - \frac{c}{2L_{IMC}} = 168234233.5 \text{ Hz} \tag{3.2}$$

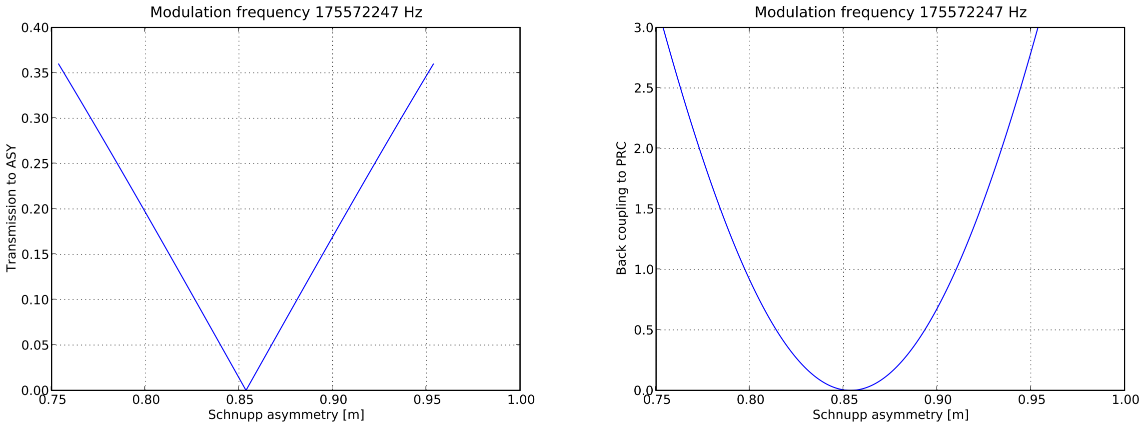


Figure 3: **Left**. Amplitude transmission of sideband field from PRC to SRC for the 176 MHz sidebands, for a Schnupp asymmetry varying around the optimal one. **Right**. Back coupling of sideband field inside the PRC when the SRC crosses a resonance.

The lengths and modulations corresponding to this choice are listed in tab. 2.

Length	**Symbol**	**Value**	**Virgo value**	**Difference**
PRC length	L_{PRC}	11.954 m	12.053 m	-0.099 m
IMC length	L_{IMC}	143.451 m	143.573 m	-0.122 m
Schnupp asymmetry	Δ	0.854 m	0.878 m	-0.024 m
Distance BS-PRM	l_P	5.884 m	5.980 m	-0.097 m
Distance BS-IMX	l_N	6.497 m	6.512 m	-0.015 m
Distance BS-IMY	l_W	5.643 m	5.634 m	+0.009 m
SB1 modulation	f_1	175548765.3 Hz		
SB3 modulation	f_2	168234233.5 Hz		

Table 2: . Lengths and modulations for the large Schnupp asymmetry option.

This large Schnupp asymmetry option has many advantages and disadvantages:

- The asymmetry can be tuned quite accurately in order to reduce the transmission of SB1 to ASY to much lower levels than in the small asymmetry case. This might prove to be very helpful in making the lock acquisition easier and in decoupling SRCL from the other auxiliary d.o.f.s.
- The lowest modulation frequency can be moved to higher values: this will ease the requirements on the output mode cleaner for DC read-out [8].
- The NI, WI and PR towers need much smaller displacements with respect to the other option: this will significantly reduce the impact on infrastructural work.
- On the bad side, if the lowest f_3 is chosen there is the possibility that signal coming from these sidebands could not be used during lock acquisition, because of the large back-coupling from SRC.
- The choice of so high modulation frequency might pose some troubles from the photo-detector and electronic point of view.

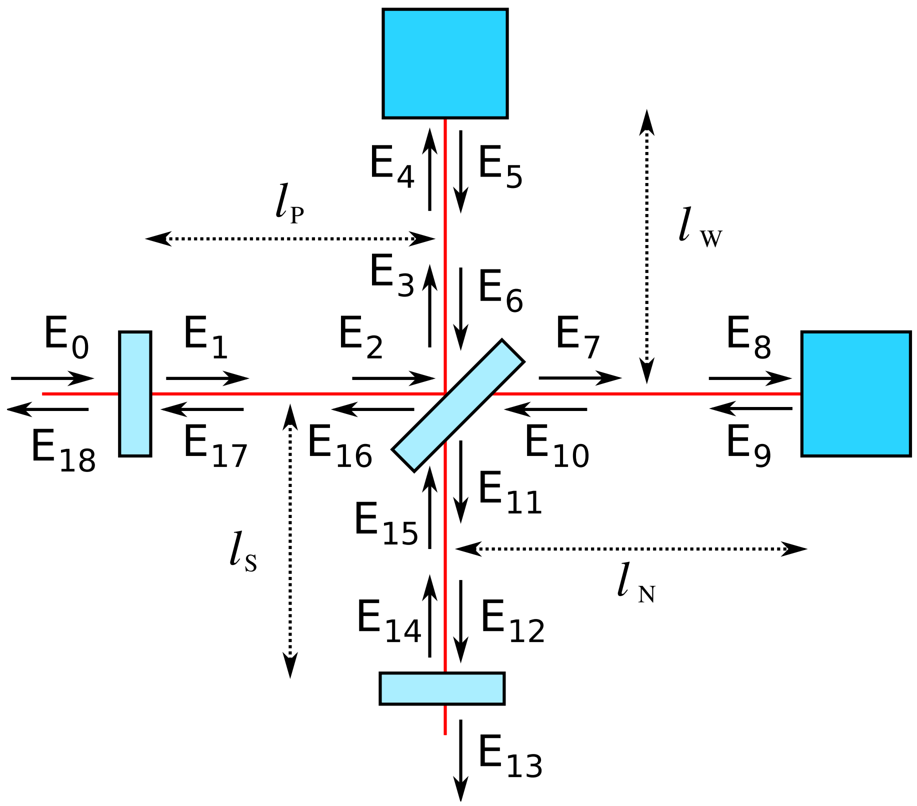


Figure 4: Scheme of lengths and fields inside the central part of a dual recycled interferometer. Amplitude reflectivity and transmissivity are denoted respectively by r_P and t_P for the PR mirror and by r_S and t_S for the SR one.

4 Signal recycling cavity length

The choice of the second modulation frequency f_2 and of the signal recycling cavity length must be made in such a way to be able to extract a suitable error signal for controlling SRCL. This is possible if the SB2 are resonant in the signal recycling cavity. In this way the sidebands will undergo a phase rotation around the correct operating point of the SRC and this can be extracted by beating with another field (carrier or sideband) not resonant.

In the previous notes [1, 2] the requirement on SB2 was to be simultaneously resonant in the PRC and in the SRC. This implied a choice of the signal recycling cavity length close to 11 m, namely 1 m shorter than the present possible configuration. The large impact on vacuum and infrastructure work has trigger the analysis of a different scenario, which is explained here.

4.1 SR-PR composite cavity

The computation carried out in [1] for the sidebands resonance inside the SRC assumed the sidebands to be simultaneously resonant in the PRC. In general this might not be true or even needed. For this reason here we consider the more general situation: the sidebands are only assumed to be anti-resonant in the long cavities (reflection coefficient equal to i). The naming convention for lengths and fields are shown in fig. 4.

In a way similar to what explained in [1], the fields inside this interferometer can be described by the following set of equations:

$$E_1 = t_P E_0 + i r_P E_{17}$$
$$E_4 = e^{ikl_W} E_3$$
$$E_7 = \frac{i}{\sqrt{2}} E_{15} + \frac{1}{\sqrt{2}} E_2$$
$$E_{10} = e^{ikl_N} E_9$$
$$E_{13} = t_S E_{12}$$
$$E_{16} = \frac{i}{\sqrt{2}} E_6 + \frac{1}{\sqrt{2}} E_{10}$$
$$E_2 = e^{ikl_P} E_1$$
$$E_5 = i E_4$$
$$E_8 = e^{ikl_N} E_7$$
$$E_{11} = \frac{i}{\sqrt{2}} E_{10} + \frac{1}{\sqrt{2}} E_6$$
$$E_{14} = i r_S E_{12}$$
$$E_{17} = e^{ikl_P} E_{16}$$
$$E_3 = \frac{i}{\sqrt{2}} E_2 + \frac{1}{\sqrt{2}} E_{15}$$
$$E_6 = e^{ikl_W} E_5$$
$$E_9 = i E_8$$
$$E_{12} = e^{ikl_S} E_{11}$$
$$E_{15} = e^{ikl_S} E_{14}$$
$$E_{18} = i r_P E_0 + t_P E_{17}$$

where k is the wave number corresponding to the selected sideband.

These equations can be solved to obtain an expression for the field inside the PRC E_1, inside the SRC E_{12} and at the beam splitter pick-off port E_{10}. Lengths are expressed in terms of the physical degrees of freedom defined in [1], equations 2.3, 2.4, 2.9, 5.5, 6.3 and 6.5. The carrier resonance conditions are already taken into account: resonant in PRC, Michelson tuned to dark fringe condition. The signal recycling tuning is also considered:

$$E_1 = \frac{t_P}{1 + r_P e^{2i\frac{\Omega}{c}l_{PRC}} \frac{\cos\left(\frac{\Omega\Delta}{c}\right) - r_S e^{2i\phi} e^{2i\frac{\Omega}{c}l_{SRC}}}{1 - r_S e^{2i\phi} e^{2i\frac{\Omega}{c}l_{SRC}} \cos\left(\frac{\Omega\Delta}{c}\right)}} E_0 \tag{4.1}$$

$$E_{12} = \frac{i t_P \sin\left(\frac{\Omega\Delta}{c}\right) e^{i\phi} e^{i\frac{\Omega}{c}(l_{PRC}+l_{SRC})}}{1 - r_S e^{2i\phi} e^{2i\frac{\Omega}{c}l_{SRC}} \cos\left(\frac{\Omega\Delta}{c}\right) + r_P e^{2i\frac{\Omega}{c}l_{PRC}} \left[\cos\left(\frac{\Omega\Delta}{c}\right) - r_S e^{2i\phi} e^{2i\frac{\Omega}{c}l_{SRC}}\right]} E_0 \tag{4.2}$$

$$E_{10} = \frac{i\sqrt{2} t_P e^{ik(l_P+2l_N)} \left[r_S e^{2i\phi} e^{2i\frac{\Omega}{c}l_{SRC}} \left(i\cos\left(\frac{\Omega\Delta}{c}\right) - \sin\left(\frac{\Omega\Delta}{c}\right)\right) + 1\right]}{1 - r_S e^{2i\phi} e^{2i\frac{\Omega}{c}l_{SRC}} \cos\left(\frac{\Omega\Delta}{c}\right) + r_P e^{2i\frac{\Omega}{c}l_{PRC}} \left[\cos\left(\frac{\Omega\Delta}{c}\right) - r_S e^{2i\phi} e^{2i\frac{\Omega}{c}l_{SRC}}\right]} E_0 \tag{4.3}$$

The configuration will be studied in the two cases of small and large Schnupp asymmetry.

4.2 Small Schnupp asymmetry

Chosen an arbitrary length of the signal recycling cavity $l_{SRC} = 11.5$ m the dependence of sidebands fields inside the PRC and inside the SRC on the modulation frequency is shown in fig. 5 for the small Schnupp asymmetry option. The RSE tuning of the signal recycling has been chosen here.

As appears clear from fig. 5, the PRC field shows resonant peaks for equispaced frequencies, corresponding to those already identified which are resonant inside the PRC. In correspondence of these resonance there are clearly also peaks in the SRC field. However this field shows other resonances that correspond to the frequencies that match the SRC length only. The behavior of fields inside the two cavities as a function of the signal recycling tuning and for different choices of lengths and modulations are shown in fig. 6. In that figure only the field of the upper sideband is shown. The lower one is specular with respect to the $\phi = 0$ axis.

If the modulation frequency is chosen to have the sidebands resonant in the PRC but not in the SRC, the resonant peak for the field inside SRC does not correspond to zero tuning. Moreover the upper and lower sidebands resonate for opposite tunings. Only if the SRC length is chosen appropriately the sideband will be resonant inside SRC for zero tuning. However there is a third opportunity, which corresponds to the resonance inside the SRC only: the field inside PRC shows a dip at zero tuning, corresponding to the peak of the field inside the SRC. Looking back to fig. 5 it is clear that the amplitude of sidebands fields inside the SRC cavity is roughly the same in both situations, since the resonance condition is met inside only one of the two recycling cavities at one time.

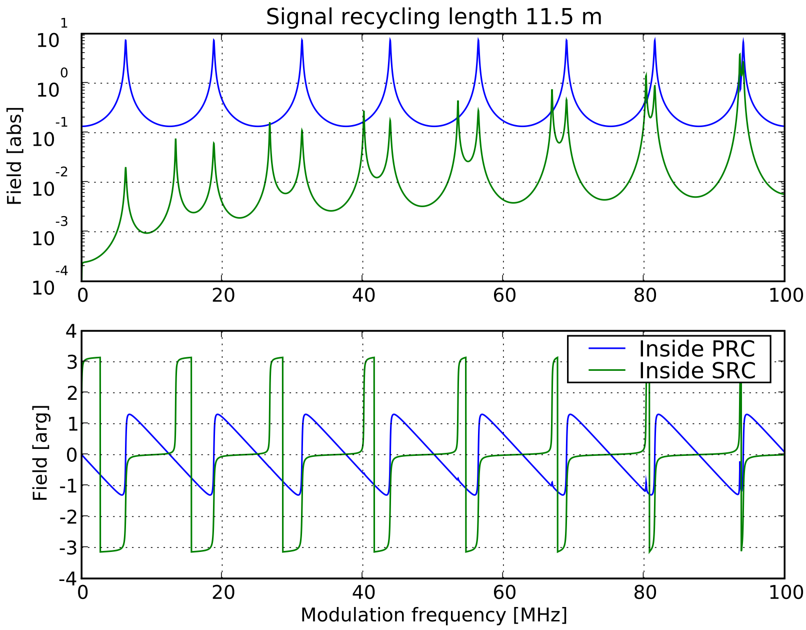


Figure 5: Dependence of fields inside PRC and SRC on the modulation frequency, for a signal recycling tuning $\phi = 0$. The frequency is assumed to be always anti-resonant in the arm cavities.

As already computed in the previous note [2], to have SB2 both resonant in PRC and SRC, the length of the signal recycling cavity have to be much shorter than the actual possible value of about 11.973 m. Indeed, the optimal signal recycling cavity lengths corresponding to various choices of f_2 are shown in tab. 3 and the only way to reduce the required displacement of the signal recycling tower is to go to quite high modulation frequencies for SB2.

Modulation Frequency	**SRC lengths**
81515709.495	11.03317851, 12.87204159
94056587.879	11.15576938, 12.74945072
106597466.263	11.24951534, 12.65570476
119138344.647	11.32352531, 12.58169479
131679223.030	11.38343814, 12.52178196
144220101.414	11.43293135, 12.47228875
156760979.798	11.47450565, 12.43071445
169301858.182	11.50992079, 12.39529931
181842736.566	11.54045108, 12.36476902
194383614.950	11.56704198, 12.33817812
206924493.334	11.59040974, 12.31481035

Table 3: Optimal signal recycling cavity length to have SB2 resonant both in PRC and SRC, for the small Schnupp asymmetry option.

If we require SB2 to be resonant only inside SRC and not in PRC, one requirement on the modulation is relaxed, but the frequency still must be a multiple of the IMC free spectral range. Assuming a signal recycling cavity length close to the actual value, the resonant peaks for PRC and SRC intra-cavity fields are shown in fig. 7 together with the frequencies that are transmitted by the IMC.

The procedure to select the correct combination of modulation frequency and SRC length can be obtained with

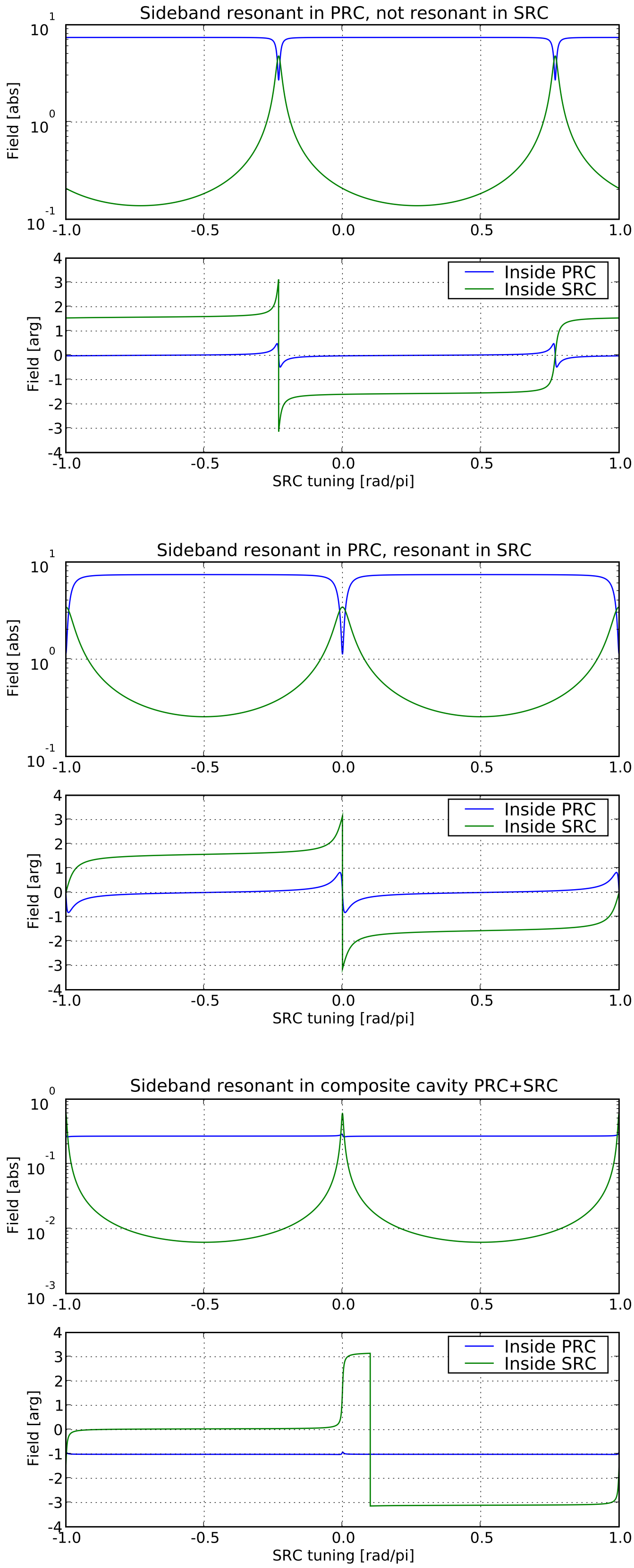


Figure 6: Behavior of upper sideband field inside PRC and inside SRC, as a function of the signal recycling tuning. **Top**: sideband resonant inside the PRC but not inside SRC. **Middle**: sideband resonant both in PRC and SRC. **Bottom**: sideband resonant in the composite cavity PRC+SRC.

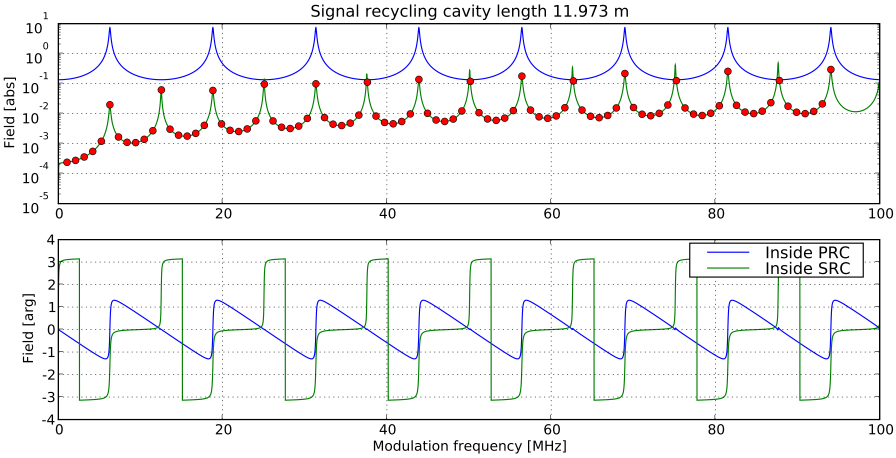


Figure 7: Field amplitude inside PRC and SRC as a function of the modulation frequency. The red dots show the frequencies which are transmitted by the IMC.

the following procedure. Chosen the approximate modulation frequency (88 MHz) the closest IMC resonance is easily found to be 87786148.7 Hz. This corresponds to an anti-resonance of the PRC cavity, being an even multiple of the basis frequency. Moreover it would correspond to a resonance of the arm cavities: however the offset from anti-resonance chosen at the beginning helps here, moving this modulation away from resonance. The detuning from exact anti-resonance can be increased to 150 Hz to make these sidebands safer. Finally the corresponding optimal signal recycling cavity length is found by maximizing the sideband field inside the SRC as a function of the length. The result is, as might be expected, that the optimal SRC length is exactly equal to the PRC one: 11.953 m.

A final small correction must be considered here: the field reflected by the cavity has a dephasing which is not exactly 180 degrees as it should be in anti-resonance. Indeed the small difference can be easily obtained from eq. 3.8 of [1] and for the parameters used here is about 26 mrad. This can be converted to a shift in the optimal signal recycling cavity length of

$$\delta L_{SRC} = \delta\phi \cdot \frac{c}{4\pi f_2} \sim -0.007\ m \tag{4.4}$$

which corresponds to $L_{SRC} = 11.947$.

In conclusion a possible set of lengths and modulations in the small Schnupp asymmetry options is listed in tab. 4.

The only drawback of this choice of resonant conditions is that the amplitude of the SB2 field inside the SRC at resonance is about a factor 30 lower than in the other case (simultaneous resonance in PRC and SRC), since the resonant enhancement of the PRC is lost.

4.3 Large Schnupp asymmetry

As explained in sec. 6.3 of [1], the sign of the sideband fields transmitted by the power recycling cavity to the ASY port changes when

$$\cos\left(\frac{\Omega\Delta}{c}\right) < r_P \longrightarrow f > \frac{c}{2\pi\Delta}\arccos r_P$$

For the nominal value of the PR power transmissivity of 7% and the small value of the Schnupp asymmetry, this happens around 320 MHz. For the larger value of $\Delta = 0.854\ m$ here considered this frequency moves down to 15 MHz. This means that for all modulation frequencies, excluded the lowest one, the resonance condition

Length	Symbol	Value	Virgo value	Difference
PRC length	L_{PRC}	11.953 m	12.053 m	-0.100 m
IMC length	L_{IMC}	143.434 m	143.573 m	-0.139 m
Schnupp asymmetry	Δ	0.04 m	0.878 m	-0.838 m
SRC length	L_{SRC}	11.947 m	11.980 m	-0.033 m
Distance BS-PRM	l_P	5.980 m	5.980 m	+0.000 m
Distance BS-IMX	l_N	5.993 m	6.512 m	-0.519 m
Distance BS-IMY	l_W	5.953 m	5.634 m	+0.319 m
Distance BS-SRM	l_S	5.974 m	6.000 m	-0.026 m
SB1 modulation	f_1	6270339.2 Hz		
SB2 modulation	f_2	87784748.7 Hz		
SB3 modulation	f_3	8360585.6 Hz		

Table 4: Lengths and modulations for the small Schnupp asymmetry option.

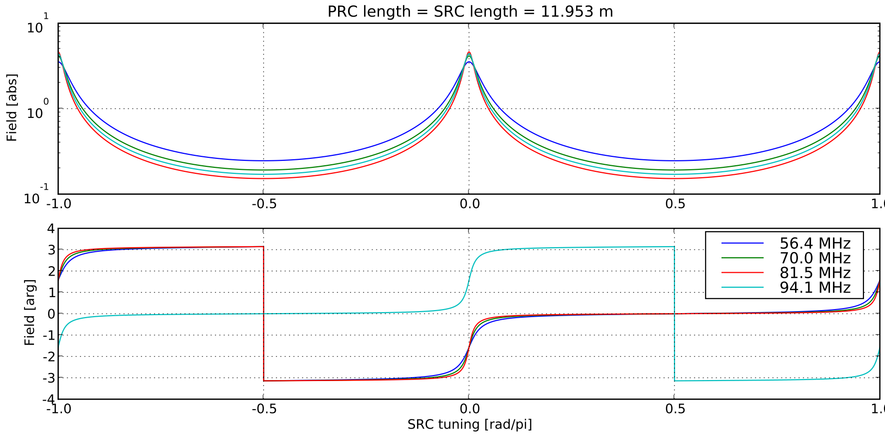


Figure 8: Sideband field amplitude inside the signal recycling cavity as a function of SRC tuning, for different choices of SB2 modulation frequencies.

inside SRC is changed: the sidebands are always simultaneously resonant in PRC and SRC if the two lengths are equal.

In this configuration any of the modulation frequencies that are resonant inside PRC could in principle be used to extract good error signals for SRCL provided its transmission to ASY is large enough. This parameter determines also the finesse of the signal recycling cavity for the sideband used to control its length, see fig. 9. A reasonable finesse should be within 20 and 100, in order to have large enough error signal without making the lock acquisition of the SRC too difficult. A possible candidate is close to 150 MHz, which corresponds to a finesse of about 25.

The possible combination of lengths and modulations for this configuration are listed in tab. 5.

5 SRCL control

For both small or large Schnupp asymmetry, a signal to control SRCL must be extracted from the beating of SB2 with the carrier or with another sideband. Clearly it is not possible to use the carrier or SB1 at the antisymmetric port, since their amplitude should be very small there. In the symmetric and beam-splitter pick-off port there will be plenty of carrier and SB1, so both a single or double demodulation should be possible.

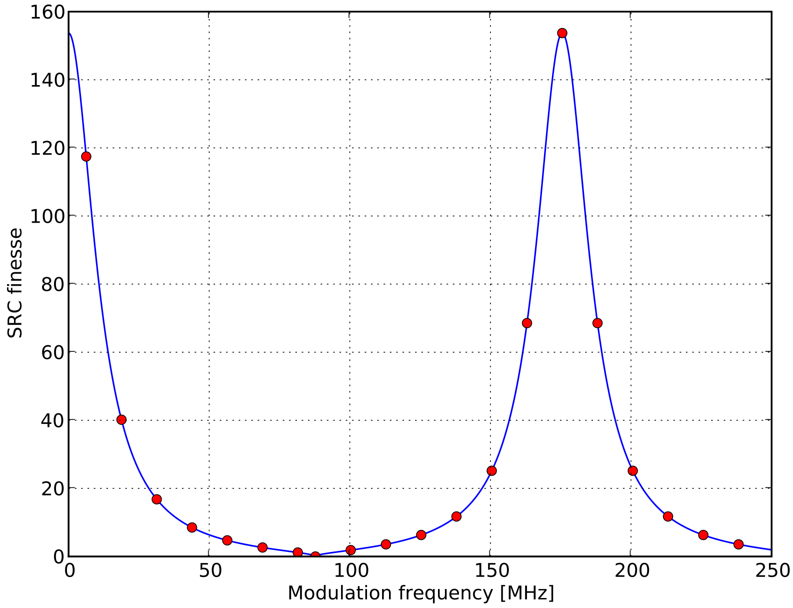


Figure 9: Dependence of SRC finesse for SB2 on the modulation frequency.

Figure 10 shows the behavior of the field at the beam splitter pick off port, in the two configurations, as a function of the SRC tuning. The sidebands behavior suggests that a single demodulation at the beam splitter pick-off might be used to obtain an error signal to control SRCL. This however must be the subject of careful simulations.

References

[1] G. Vajente, *"Note on Signal Recycling I: Field equations"*, VIR-030B-08 (2008) 6, 7, 10

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Length	**Symbol**	**Value**	**Virgo value**	**Difference**
PRC length	L_{PRC}	11.954 m	12.053 m	-0.099 m
IMC length	L_{IMC}	143.451 m	143.573 m	-0.122 m
Schnupp asymmetry	Δ	0.854 m	0.878 m	-0.024 m
SRC length	L_{SRC}	11.954 m	11.980 m	-0.026 m
Distance BS-PRM	l_P	5.884 m	5.980 m	-0.096 m
Distance BS-IMX	l_N	6.497 m	6.512 m	-0.015 m
Distance BS-IMY	l_W	5.643 m	5.634 m	+0.009 m
Distance BS-SRM	l_S	5.884 m	6.000 m	-0.116 m
SB1 modulation	f_1	175548765.3 Hz		
SB2 modulation	f_2	150470370.3 Hz		
SB3 modulation	f_2	168234233.5 Hz		

Table 5: Lengths and modulations for the large Schnupp asymmetry option.

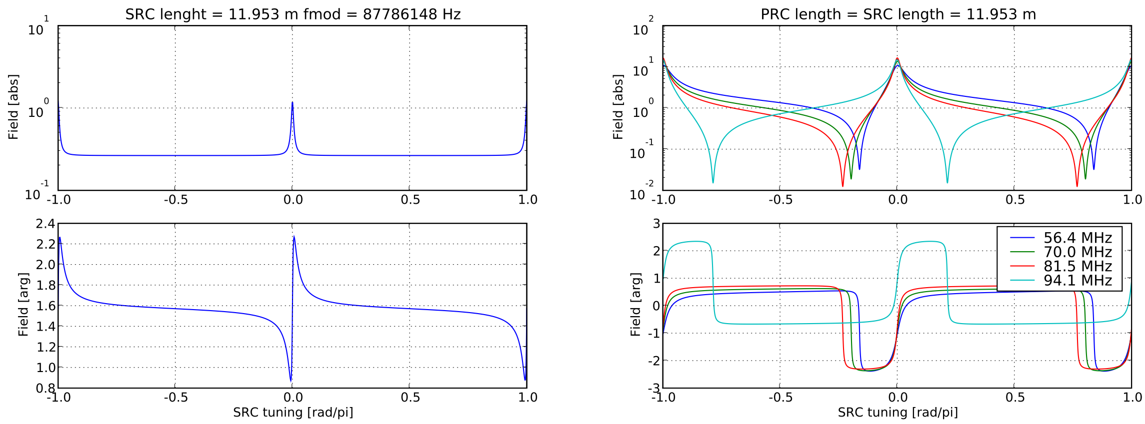

Figure 10: Field amplitude at the beam splitter pick-off as a function of the SRC tuning, for small Schnupp asymmetry (**left**) and large Schnupp asymmetry **right**).