JCMT Work Packages for the eSMA

Phase I & II, 230 GHz tests

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1. Introduction

This document attempts to disseminate the work required for bringing the JCMT into the extended SMA, eSMA for short, the combined interferometer formed between the SMA dishes and the JCMT and CSO. Particularly it focuses on the work required in the first year, aiming at getting first fringes and testing at 230 GHz, proving the concept will work. This analysis, however, cannot be carried out without making some assumptions about the more definite state of the JCMT – SMA connection. Brief discussions about the future mode of operations, the signal connection and software interfaces are therefore part of this document. The scientific case for the eSMA was the subject of a report to the JCMT board, which we will refer to as 'ScienceCase'. We will not concern the scientific arguments for the project here.

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2. Assumptions about future operations

2.1. Receivers

It is clear that the 345 GHz band is the main scientific interest. For testing 230 GHz is important. On the SMA side it is felt that there are many nights on which 230 GHz is the most effective observing mode. It is deemed necessary to allocate fixed periods during a semester for the operations of the eSMA, so it seems a permanent 230 GHz setup is required for the eSMA, besides the 345 GHz. Without a 230 GHz operational system it would be impossible to even do testing on nights that are allocated exclusively for eSMA use, but have weather that does not allow 345 GHz. The 'ScienceCase' also advertises the use of the eSMA at 690 GHz, although it is not yet clear how much (long baseline) interferometry at 690 GHz can be done from Mauna Kea. At this point we defer this issue; SMA stand-alone experience and eSMA operations at lower frequency will provide important input for this decision.

There are basically two ways to outfit the JCMT for the eSMA. The first uses HARP for 345 GHz operations and seems to be the cheaper way forward (option A). An alternative could be to use RxB3 for the eSMA (option B), this is a much more involved path, but could have some advantages for the scientific return of the project.

In option B, the work involved would be to install the eSMA interface in the cabin, retrofitting first RxA3 and doing initial testing. The next step would be to upgrade RxB3, which is much more work as it has 2 IF outputs, of which at least one would need to be modified. The LO/IF box could stay in the cabin near the 2 (or 3 if you include RxW) receivers. Moreover, the introduction of HARP would not be critical for reaching the eSMA operational stage. The eSMA could benefit from dual sideband operations at 345 GHz, although it could be that in practice the SSB HARP outperforms RxB3 in DSB. Drawbacks are that the JCMT would have to continue operations of two 345 GHz systems (HARP and RxB3), which would be expensive. The 3 receivers and LO/IF box for eSMA will take up much of the space in the cabin, possibly interfering with the arrival of SCUBA2.

Option A will work towards a setup for the eSMA that focuses on HARP. The LO/IF box for interfacing to the eSMA will go to the right Nasmyth platform. HARP has the proper IF output band to connect to the eSMA directly. Moreover it has a K mirror to track the polarization according to the eSMA specifications. So option B requires much less engineering effort. The complicating factor is that it is deemed necessary to also have an operational RxA3 at the same time. As in option A, this receiver needs to be upgraded. However, this receiver is located in the cabin, rather than the Nasmyth focus, implying that the connection from the SMA must reach two different places. The same problem could come up for RxW. Another drawback is that HARP, though supposedly more sensitive, is intrinsically single sideband. The possible loss of continuum sensitivity has been recognized accordingly in the 'ScienceCase'. The HARP receiver will need to be interfaced to the eSMA LO control. This interface will be slightly more demanding than the interface for a single pixel receiver, on the other hand HARP will have the advantage of being remotely tuneable.

It is assumed that option B is too expensive and does not fit the JCMT long-term operations model. Option A has been budgeted and this solution will be pursued below. However, the first 2 phases of the implementation, which focus on tests with RxA3, are mostly identical for both options, leaving the option to change plans until the end of 2004.

2.2. eSMA Operations

Operations of the eSMA are to be completely controlled from the SMA side. The SMA is typically manned in the first half of the night and currently some hands on work can be carried out to tune the receivers at the beginning of the track. In principle the whole operation can be controlled remotely in the future, and usually the second part of the night is already run from Boston. The aim must be that the same mode of operation will hold when the JCMT joins the eSMA. All actions should be allowed under computer control and interfaced to the SMA control. However, it seems pragmatic to follow the current SMA practice to have personnel available at the start of the night, to make sure the track starts up properly and solve problems with, for instance, receiver tuning. After setting up the JCMT for eSMA operations, a single JCMT person could remain in the SMA control building during the shift. It seems that eSMA observing should be planned ahead and fixed for something like a week. At the JCMT and CSO dedicated setups for eSMA may be required and the SMA array may need to be in certain configurations. It is unlikely that there will be flexibility to adjust the schedule based on the weather.

Typical observations of the SMA have either a single track per night or two tracks with the same frequency setting. Sometimes more than one source is targeted in the same observation. Doppler tracking is done by changes in the LO, controlled by the correlator software. Normally these stay within the range that keeps the receivers in lock. Most projects will use a few array configurations to complete uv-coverage. Similarly eSMA projects can have different configurations that need to be observed several weeks apart. It does not make sense to include the JCMT when the SMA is in a compact configuration, and it may be scientifically justifiable to include the JCMT only in the extended configurations for a project. In these cases it brings extra sensitivity to the long baselines, which could be crucial for (self-) calibration.

2.3. Calibration

Current observation modes for the SMA include 10 – 15 minute scans on targets, interleaved with one, maybe two, 5 –10 minutes scans on a phase calibrator. As good calibrators are rare, these may be 20 – 30 degrees off. The JCMT being a larger dish, not optimized for interferometry, will have the slowest slew and also possibly the most demanding pointing constraints. Some observations could include a scan on a pass-band calibrator, likely a solar system body. At the SMA there are schemes anticipated for WVR calibration and transferring calibration from one of the lower frequencies to the 690 GHz band. The WVR technique could eventually be useful for the eSMA, particularly as this array will use long baselines. The inter-band calibration is excluded; as there is no way the JCMT will have simultaneous receivers.

Pointing calibration is done at the beginning of the night and typically once or twice during the night. This is done in interferometry mode; single dish pointing is done only for SMA antennas after they have been moved to a new pad. There are no special command interfaces to the antennas for the pointing sequences. It is desirable that the JCMT participates in this, implying however that an interface is needed to feed the offsets back to the JCMT. This follows the model of the SMA, where pointing offsets are absorbed by the antenna logic and source positions are passed to the telescopes in high level, astronomical coordinates. At the SMA side the procedures for pointing need to be adopted for inclusion of the JCMT, which has a smaller beam.

The SMA currently uses a fixed focus, which is set at a median value acceptable for all elevations. It will adjust focus dynamically in the future, but it is not clear how often the focus will be adjusted. The JCMT has focus procedures that search for a focus position with optimal gain while observing a bright source. It is current practice to determine the JCMT focus several times per night, which is necessary because the optimal focus has a temperature dependence. As the output of the receiver is typically routed to the SMA side, this implies that the SMA will have to implement focusing, at least for the JCMT, before joint eSMA operations can start. This item by itself seems to require a lot of interfaces. It seems inefficient to implement single dish observing modes to be controlled from the eSMA, as it would require synchronization with the JCMT chopper. Another option could be to have a T-splitter in the IF output, in order to allow one of the JCMT backends to be used for focusing (and pointing). In this case a high level command to solve for focus (and pointing) needs to be implemented. Before a decision is made on this issue, it needs to be evaluated how much focusing is really required. Also, it could be investigated whether it is possible to do interferometric focusing, just like pointing. If all could be done in an interferometry mode, this would be the preferred option, as it follows more closely the control model in which the eSMA is run from the SMA console.

In addition the JCMT has active focus adjustments based on the elevation of the pointing. As these corrections attempt to keep the total optical path equal for all positions in the sky, it is felt that they probably also yield an improvement of the phase stability of the JCMT in interferometry mode, as long as the tracking is continuous and the steps are small. So, this could remain active during eSMA observations.

The eSMA will operate in a single linear polarization mode, as the SMA is doing currently. The same polarization orientation needs to be captured from all antennas. The SMA has a linear polarizer that works with a mirror, which sends one beam to one receiver and the other with conjugate polarization to another. The optical layout of the SMA receiver carousel is such that certain receiver combinations can be used this way in complementary polarization. The receivers of the SMA are fed through the Nasmyth focus. Therefore their signal rotates on the sky during a track differently from the JCMT receivers (HARP is on the opposite Nasmyth focus with respect to the SMA). The JCMT will have to take measures to observe the same polarization. For HARP this is built into the optics and one is left with the problem of controlling this properly, although we are currently not certain whether this will introduce an additional phase signature. For RxA3 this needs to be addressed by separate hardware, which could be Rover eventually. Another option could have been to install $\lambda/4$ plates in all telescopes and observe circular polarization, but this would reduce the sensitivity of the SMA – SMA baselines too much.

For calibration of the system temperature a load is switched into the beam. At the moment the SMA has only an ambient temperature load, although for higher frequency a cold load is planned too. The load is typically switched in during slews. The total power is measured in the LO/IF box, so it seems the same scheme can be used for the JCMT and the measurements are directly available for downstream processing. Possibly an interface is needed for defining the temperature of the load.

The SMA correlator will currently flag output data when the telescope is slewing. This information must flow to the correlator from the JCMT. In the future the status of the receiver will also be used to flag correlator output, although this is currently not operational at the SMA. This will be easy when the SMA phase-lock is used at the JCMT.

2.3. Correlation and processing

In order to make the JCMT operate as a part of the SMA, its presence needs to be catered for in the SMA control. As the SMA is designed to operate 8 x 2 receivers, there is enough hardware for running it in 10 x 1 receiver mode. However, the current Walsh function implementation has states for 8 receivers, and needs to be extended to run for 10 eventually. The correlator has room for 2 times 28 baselines and will therefore in principle be able to accommodate 1 x 45 baselines. It needs to be verified that these correlator configurations allow all interconnections to be made. Certainly, new correlator modes for 10 antennas need to be made available.

At the moment the SMA has outgoing signals for 8 receivers and the remaining 8 are getting ready to be installed. A patch rack for the outgoing signals exists in the basement, which includes the CSO and JCMT. Making a connection to the JCMT at the SMA control building does not seem to be a critical issue.

Another essential step in this process is to get the initial position for the JCMT. In normal operations the JCMT position can be obtained from a baseline solution performed with the eSMA, but this requires a fully operational system. For first tests the JCMT position with respect to the SMA needs to be estimated from external measures. This is supposedly straightforward, as the SMA has used the same geodetic reference on the Mauna Kea site that was used for the CSO – JCMT baseline. In addition the fibre length needs to be measured and inserted in the software that handles the delays. The SMA operates with a fixed cable length and no active return loop calibration. A similar issue is the axis offset for the JCMT receiver. There may be additional offsets from the track stability, which could have been investigated during the JCMT – CSO experiments.

As a side issue we like to mention that access to the data is through the SMA processing setup. The system for calibration is currently based on the OVRO data reduction scheme, implemented as IDL routines. Although in principle exportable, it seems that it currently requires close interaction with the SMA staff.

3. JCMT eSMA configuration, the long-term perspective

This section deals with components one by one, outlining in basic terms what work is required to incorporate the JCMT in the eSMA. Specific steps for the first year, 2004, are listed in section 5.

3.1. Where to go?

Following option A from above, HARP is the most important receiver for the eSMA, and it will be in the Nasmyth focus. Therefore, it seems that the permanent setup will have the SMA components on the right Nasmyth platform. There seems to be sufficient room there for a single rack with eSMA equipment. This implies that a solution has to be found to reach RxA3, which is deemed important for operations too. Maybe it is possible to run this with long cables; maybe a separate phase lock system near RxA3 is needed. When RxW needs to be interfaced as well, this will be even more demanding, because its phase stability requirements at a higher frequency will be more stringent. A possible, but expensive solution could be to have two eSMA interface boxes, just like a genuine SMA antenna, one in the Nasmyth focus and one in the cabin. Fibre is laid out for this, but this would be a very expensive solution estimated at 50k$, requiring a duplication of many of the components acquired from the Smithsonian. It seems possible to make the 4-6 GHz LO available to both.

A temporary solution for initial testing with the 230 GHz band in the cabin is needed. This seems possible in the pre-SCUBA2 era.

3.2. Fibre

The SMA uses so called Sumitomo fibre for distribution of the analog LO and transport of the IF. This material is absolutely essential for the eSMA operations, as fixed cable length is assumed in the correlation. Furthermore this fibre is now obsolete. Sumitomo low expansion optical fibre cables have been pulled between the SMA and a manhole between the JCMT and the CSO. There is one cable for the JCMT and one for the CSO. Since the CSO - JCMT baseline interferometry experiment there is a Sumitomo optical fibre cable (also with 3 fibres) between the JCMT and CSO that passes through the same manhole. This cable is being reused for the eSMA and the new cables have been spliced with the existing old cable. Thus there are now three fibres from the SMA to each of the JCMT and the CSO. However, there are no direct fibres between the JCMT and CSO any more.

Each cable contains three fibres, which is enough for the Gunn references and two IF channels. The planned mode of operation with only one IF channel from each telescope, leaves one spare fibre for each telescope. Note that the fibres not have been tested. Within the JCMT dome there is probably 300m extra cable from the original link between the receivers and the DAS.

There is also multi-mode fibre used for digital communication such as control commands. These have been pulled several years ago as well. Within the JCMT building these can be patched as needed.

3.3. Fibre interface box

The SMA is delivering the fibre receiver boxes. These boxes receive Gunn reference frequencies on one fibre and transmit the IF band on another fibre. On the latter fibre a 200 and ~109 MHz signal comes in, which carries the rapidly varying frequency component that is used for fringe stopping, Doppler tracking, and the Walsh cycle switching. Together with the Gunn reference these two frequencies are used by the phase lock system. At the moment there has been an order for a single IF system, so in principle this system will have to be interfaced to all receivers at the JCMT side.

3.4. Phase lock system

The SMA will supply a phase lock system of the SMA design. The major advantage is that the control and feedback is easily interfaced with the SMA antenna computer for the JCMT. In principle, testing could be done without a SMA phase lock system, by taking the LO reference signals from the SMA, but using local phase lock systems. In the long run this is not an elegant solution because SMA control and correlator will need to know that the JCMT Gunn oscillator is locked.

3.5. Receiver 230 GHz

This band is used for initial testing. It is desired to have this system operational throughout the lifetime of the eSMA.

The SMA operates with an IF centred at 5 GHz and a bandwidth of about 2 GHz, while the current RxA3 receiver at the JCMT has an IF centred at 4 GHz. To provide a fully operational system at 230 GHz, the RxA3 needs to be modified to operate with a 5 GHz IF. The current DAS backend will not work with a modified IF, but ACSIS will be able to deal with both. It is planned that ACSIS is commissioned before the eSMA testing, else if RxA3 is modified the new IF frequency needs to be down converted to work with the DAS. For testing purposes it would also be possible to up convert the IF to 5 GHz without upgrading the receiver. A third option would be to use a narrow overlap and modify the correlator software to select a different IF range from the JCMT. However, all of this is additional work that not is needed if ACSIS is commissioned before the testing. The aim is to modify RxA3 for all stages of the eSMA project. This, however, makes the eSMA project dependent on the ACSIS commissioning.

The upgrade of RxA3 is assumed to be relatively straightforward; the main concern seems to be the mechanics. The mixer block has no frequency dependent IF matching circuit. In fact RxA3 was going to have an IF frequency of 1.5 GHz. However, HIA had problems with the 1.5 GHz HEMT amplifier and used a 4 GHz HEMT instead. RxA3 was delivered with a 4 GHz IF after also the warm IF electronics was modified to 4 GHz. Chancing the 4 GHz HEMT to a 5 GHz HEMT is thus assumed to be sufficient. No mixer block modifications are planned. Naturally the warm IF electronics also has to be replaced. The new LNA for this upgrade has been ordered and received. There will be a period during the upgrade that RxA3 is not available for observations.

3.6. Gunn 230 GHz

The current mixing scheme for RxA3 is not compatible with the SMA, because it uses a different multiplication factor in the last stage. In principle this could be solved by using the LO for the second receiver, not used for the eSMA, to drive the JCMT RxA3 Gunn. This introduces some logistic issues, but moreover it would introduce extra noise as not all receivers run on an identical phase signal. We conclude that for operations with the SMA a new Gunn needs to be obtained. Initially this can be done with a Gunn that is also mechanically and interface compatible with the SMA control computer. Such a system can be borrowed from the SMA, which would allow use of their phase lock system and direct control from the SMA.

However, the system from the SMA will be tuneable from 177 – 256 GHz, while RxA3 covers 215 – 270 GHz. As swapping Gunn oscillators all the time between JCMT and eSMA operations is not ideal, for the long term a new Gunn would be needed for RxA3 that is compatible with both the JCMT and eSMA requirements. This should be done if 230 GHz is deemed important for an operational eSMA, where it should be realized that there is probably little opportunity for flexible scheduling between the eSMA and single dish JCMT. The delivery time for a new Gunn is at least 6 months. Including the multiplier this would amount to approximately 15 – 20k$. A decision is needed here.

3.7. Receiver 345 GHz

At this frequency HARP will be the receiver. It is a 4 x 4 array aimed at fast spectral line mapping, expected to arrive in spring 2005. The current RxB3 will then be taken out of operation to save on costs and make space available in the cabin for SCUBA2. HARP is a 16-channel single sideband system with sideband rejection built into its optics; it therefore imposes a few specific control issues on the interface definitions.

For one thing, it does require the specification of sideband to be part of the interface definition; in order to make sure HARP delivers the right sideband, which contains the primary interest of the user. Furthermore, it needs to be specified at the JCMT side, which receiver from the array is to be used. This needs to be reflected in the telescope pointing as well. There will be HARP settings that are optimal for usage of a single feed and these methods, for example for LO distribution, need to be invoked.

3.8. Gunn 345 GHz

HARP has a complex system to drive 16 receivers. However, this system is compatible with the LO requirements for the eSMA. The LO and DLL reference signal can be fed to HARP. It will be tuneable with computer control. The SMA control computer will request a specific observing frequency and this can be passed on to HARP.

The complication is that when using HARP's phase lock system, the SMA control does not know directly whether the receiver is locked. It seems more advantageous to use the SMA phase lock system in this case. However, this implies that the control loop for locking the receiver does not close on the JCMT side. So, tuning settings can be applied but it is beyond HARP, whether the tuning was successful. If it is successful, this is not a problem, because the SMA can monitor this. If it is not, a manual iteration has to be started. We imagine that this can be done remotely from the SMA control building but does require operators present at the start of a shift. This solution seems to require re-cabling the HARP phase lock system every time the JCMT is transferred to eSMA mode. It is possible that this mode of operation requires intervention in the HARP software to allow operation without the lock feedback loop being closed.

3.9. Receiver 690 GHz

The RxW receiver operates in the JCMT cabin. It can be used in dual sideband mode and its tuning is currently manual. Its tuning is compatible with the SMA setup, but its IF would need to be upgraded. It currently has 4 IF outputs, but possibly only 2 would need to be upgraded to work with the eSMA. Work on this depends on a positive evaluation of 345 GHz eSMA operations and 690 GHz SMA results.

3.10. Polarizer

The SMA has all receivers fed through what they call the right Nasmyth focus (right when looking into the dish). Typically the low frequency receivers will have the opposite polarization from the high frequency. Some JCMT receivers are in the cabin, using the Cassegrain focus, and HARP will use the other Nasmyth (called right when looking from the back of the telescope). So all JCMT receivers will have to actively have their polarization modified to track the SMA orientation.

For HARP this seems a software issue only as it has a built in K-mirror, allowing it to rotate the polarization under computer control. However, we are not sure whether this does not also modify the phase response of the receiver with every motion. In this case it is probably deterministic and corrections for this should be made, presumably off-line in the data reduction. This issue needs further investigation.

For the other receivers the polarization needs to be rotated with a $\lambda/2$ plate. The current heterodyne polarimeter system will be used prior to the commissioning of Rover. In most cases the rotation is slow and only a quasi-static update is required. A manual (mechanical or remote) rotation of a heterodyne polarimeter system wave-plate is sufficient for testing.

3.11. SMA Antenna computer

All SMA control to the telescope runs through the antenna computer. This is a PowerPC mounted in a VME rack. It receives commands through RCP and reflective memory, which is also used to report back the antenna status. At the moment this computer runs LynxOS, but the SMA is considering an upgrade to Linux. In the SMA setup this computer controls a number of hardware systems directly.

A similar system is to be used at the JCMT and it is desirable to make this the only interface to the JCMT functions, in order to make the JCMT look like a standard eSMA element. Probably not all the standard SMA functions need to be translated for use at the JCMT. In addition a number of interfaces will be used with identical hardware. Examples of this are the control of the LO box, the phase-lock unit, and possibly an SMA Gunn for RxA3. For a number of other functions an interface layer will need to be implemented on the antenna control computer, which translates eSMA actions to an ASCII serial interface.

3.12. Software

The detailed software interface is the subject of a different memo, below is a bulleted list of items that this layer will need to deal with.

- To JCMT: position telescope commands, these are mostly in RA & Dec, but offsets can be used for mosaicing modes.
- To SMA: off-source/on source status information for correlator flagging.
- To JCMT: switch in load, mostly done during slew.
- To JCMT: switch out load.
- To SMA: temperature of the load.
- To JCMT: set receiver to frequency (high level command needed for HARP).
- To JCMT: accept pointing offsets (azimuth, elevation)
- Alternative: do pointing and adopt (no human intervention?)
- To JCMT: accept focus offset (Z only)
- Alternative: do focusing and adopt (no human intervention?)
- To JCMT: deliver upper/lower sideband

In addition there are software tasks that seems to be under static control, e.g. need to be set for eSMA observing but do not require an active communication protocol.

- Transfer overall command to SMA
- Use specific single pixel in HARP (could use another one for pointing?)
- Emulate polarization like eSMA Nasmyth (different for HARP & cabin receivers)

- Accept operations without apparent phase lock (HARP)
- Switch on/off automatic focus adjustments

3.13. WVR

Currently the SMA is not yet using WVR data for phase calibration. However, the JCMT has installed a similar system that can be used when such calibration is successfully applied at the SMA.

3.14. JCMT parameters at the SMA control

For operations of the eSMA it is necessary to have a number of JCMT telescope parameters set in the SMA control software. Possibly a few routines need to be upgraded. The position and axis offset must be entered in the correlator software along with its cable length.

For routine observations it is necessary to enter the axis limits and slew rates into the control as well. There may be different constraints for observing near Zenith. In order to have efficient observing, it may be required to make the eSMA control aware of the cable wrap constraints at the JCMT, in order to avoid unnecessary long slews. For pointing it should be taken into account that the JCMT has a smaller beam and hence requires smaller steps. If focus calibration is going to be done the SMA control should be aware of the range in steps.

Automatically tuning the receivers requires the SMA to know the appropriate voltage settings for the Gunn oscillators to be used and, in some cases, the look-up tables for the motorized backshorts. This applies to a possible new RxA3 Gunn.

4. Project phases:

There are a few phases recognized for the inclusion of the JCMT into the SMA. These have been modified somewhat from earlier plans. They are listed below, with a short description of the work required and the milestones to achieve.

I. **First fringes at 230 GHz (RxA3)**
   Connect the fibre and LO/IF box to the cabin. Get fringes at 230 GHz, manual telescope control, calibration and polarization.

II. **First images at 230 GHz**
   Same connection to receiver, but telescope control allows source switching, pointing and load calibration, and automatic polarization control. SMA upgraded to work with more than 8 stations.

III. **Transfer to 345GHz (HARP)**
   Move interface point to Nasmyth, interface to HARP, repeat all milestones at 345 GHz.

IV. **Pilot program at 345 GHz**
   Limited number of user eSMA project at 345 GHz only. Complete control of functionality from SMA building.

V. **Routine operations at all frequencies**
   Interface to the RxA3 (and RxW) receivers at the cabin, allowing flexible observing.

5. Phase I

5.1. Goal of phase I: first fringes

The initial goal for the project is to get fringes between the JCMT and CSO at 230 GHz. A small set of observables will be required to show that the signal connection between the telescope works adequately, that a phase stable operation can be obtained, that the JCMT can be properly absorbed into the SMA correlator, and to show that the JCMT performance is up to expected sensitivity. Important measurements to be made are:

- Show correlated flux between the JCMT and at least one SMA antenna.
- Show that phase in time is comparable to SMA baselines with comparable length.
- Produce closure phases to show that remaining phase fluctuations are antenna based.
- Show that the correlation amplitude is according to expectations.
- Show cross power phase is well behaved.
- Possibly show a cross-correlation of a spectral line.

All of these points require only a short observation of a few minutes and no source changes. The verification of this milestone requires access to the SMA data reduction facilities.

5.2. Minimal setup for Phase I

The minimal setup for phase I requires delivery of the LO/IF switch box and installation to the cabin. It should be realised that the cabin will probably not be its permanent place.

In principle a narrow IF overlap with the eSMA is sufficient for first fringes. It has been discussed whether it is possible to achieve this overlap with the current 4GHz IF, by choosing a narrow overlap and selecting a different part of the IF return signal at the SMA correlator for the JCMT. Although this is in principle not impossible (as far as we know now), it seems a waste of effort to go this route. So, for phase I the upgrade of the IF output is also deemed necessary. This can only be done after the commissioning of ACSIS, or the JCMT looses its 230 GHz capability temporarily.

It is definitely also required to upgrade the Gunn of RxA3. The fast way forward is to borrow one from the SMA, in which case one might also use it directly under the SMA phase lock control. This requires the SMA type control computer to be installed at the JCMT and to have it interfaced to the SMA, including the reflective memory setup.

The telescope tracking can be organised independently for this test, as can pointing and focusing. The phase I milestone does not require accurate sensitivity calibration, so a manual switch of the load should suffice.

All in all, there seem to be no software interfaces for phase I. And there is no requirement to hook the SMA control computer to the local environment at the JCMT.

At the SMA side the requirements are fairly minimal too. As only a few antennas need to be operated there is no need for special correlator modes or extra Walsh stages. The LO distribution and IF return for the JCMT need to be patched to the correlator. A position for the JCMT needs to be incorporated into the SMA correlator.

5.3. Work packages for phase I

It is assumed the SMA will deliver a phase lock unit, a fibre interface unit (equipped for one IF channel), and an SMA style antenna computer with software as well as assorted cables. At least the phase lock unit and the fibre interface unit are needed for the test phase. The antenna computer is useful when we use an SMA Gunn for RxA3 in testing.

It is also assumed ACSIS will have been commissioned before testing starts. This would allow the upgrade of RxA3 without affecting normal observing without extra work. If ACSIS commissioning were delayed, an option would be to start modification of RxA3 anyway. This would leave the JCMT without 230 GHz capabilities for a short period.

The following tasks are identified, following the numbering of section 3:

5.3.1. Where to go

For phase I and II we will set up RxA3 in the cabin, where it is already is and the fibres end now.

5.3.2. Fibres

1. Confirm the amount and lay of the Sumitomo optical fibres and cables inside the JCMT: This was done, the optical cable was found in the cabin, while there is another cable between the cabin and the JCMT computer room. The delay compensation was mounted in a special rack, which is no longer at the JCMT.
2. It seems there is not much work needed to arrange the layout of the cables in the cabin and no splicing should be required.
3. Test the optical fibres between the SMA and the JCMT and measure their length. The SMA has the right equipment and manpower for this.
4. Possibly, installation of suitable optical fibre connectors is required, if the current ones not can be used.
5. The communication fibre was found and seems to run directly to the cabin. This fibre needs to be tested too.

5.3.3. Fibre interface box

1. After delivery, these 2 boxes must be mounted temporarily in the cabin. Fibres must be connected.

5.3.4. Phase lock system

Assuming we use an SMA Gunn for the testing, this should be almost ready to use.

1. It must be mounted close to the receiver.

5.3.5. Receiver 230 GHz

For phase I it is required to upgrade the RxA3 IF:

1. Procure HEMT amplifiers suitable for use with the SMA (covering at least the band 4-6 GHz). The new HEMT we are considering is much smaller and have lower power consumption than the current HEMT. It fortunately also requires fewer cables into the Dewar. This is already done.
2. Procure a suitable isolator for the HEMT. The HEMT considered is absolute stable and an isolator might not be needed. However, testing before procuring the isolator would require a special shutdown with the receiver in the prep-room. It is unlikely this will be possible.
3. Make a layout for the cold part; this involves making an assessment of the current mechanical situation.
4. The HEMT will need a new power supply. This needs to be designed and built or procured.
5. Install the new HEMT and isolator in the Dewar. Install the new power supply.
6. Establish the specifications of the current RxA3I IF chain outside the Dewar. Design a new IF chain covering at least the SMA IF range taking the gain of the new HEMT as well as the ACSIS design into account. Also the space a power supplies in the RxA3 electronics rack needs to be considered.
7. Procure the needed components and build the warm IF component.
8. Plan a shutdown of RxA3 for the modifications; transport the receiver to the prep-room, assemble and test the receiver with the new HEMT new warm IF chain.
9. Modify the RxA3 micro hardware and appropriate JCMT software.

5.3.6. Gunn 230 GHz

1. A new Gunn has to be found that is compatible with the SMA mixing scheme. This would typically be a short-term solution.
2. Gunn must be mounted on RxA3
3. Test with SMA phase lock and SMA control

5.3.7. Receiver 345 GHz

No action in phase I

5.3.8. Gunn 345 GHz

No action in phase I.

5.3.9. Receiver 690 GHz

No action in phase I.

5.3.10. Polarizer

1. For phase I a manually rotated system will suffice. This needs to be installed.
2. Ideally, it needs to be worked out how orientation should be during test.

5.3.11. Installation of SMA antenna computer

1. Needs to be installed in cabin, hooked to communication fibre, no connection to JCMT control needed in phase I
2. Connect to RxA3, must be able to control from SMA

5.3.12. Software

It seems no software is needed for phase I.

5.3.13. WVR

No action in phase I.

5.3.14. JCMT parameters at SMA control

1. JCMT position must be measured and inserted in correlator model.
2. Fibre length must be entered after being measured.

5.3 Milestones

The work for phase I is inserted in the Gantt chart below (Figure 1), where it is assumed that all manpower necessary will be made available. It can be seen that first fringes can be obtained towards the end of 2004. The schedule appears to depend critically on the commissioning of ACSIS, but could start without that being completed. There are a number of phase II steps that can be done in the same period, notably on software.

A number of milestones can be identified, leading to first fringes:

1. First light for RxA3 with upgraded IF using ACSIS.
2. Successful single dish test of RxA3 with borrowed Gunn.
3. Communication with SMA antenna computer at JCMT.
4. Successful RxA3 tuning with SMA control.
5. Successful RxA3 IF return, possibly using calibration load.
6. First fringes.

6. Phase II

6.1. Goal of phase II: first image

The goal of phase II is to create an operational system at 230 GHz that is ready for test observations and a few pilots. This mostly involves turning the experimental setup of phase I into a system that can be controlled from the SMA. It has a number of software interfaces to be completed and verified. The most important thing to demonstrate is that the JCMT can operate in a 9 or 10 antenna array. Important measurements to be made are:

- Smoothly observe a complete track with eSMA.
- Source changes to phase calibrator can be made from SMA control.
- Load calibration is under remote control.

- Pointing is under remote control
- It is possible to process the data and get a reasonable image

These points require a single track only. After this is completed the 230 GHz system should remain operational for several months for further testing and possibly pilot projects. The verification of this milestone requires extensive use and in depth understanding of the SMA data reduction facilities.

6.2. Minimal setup for Phase II

The hardware used in Phase I can remain in place for most of phase II. The main difference is that a connection for the antenna computer needs to be made to the JCMT control. In addition an automatic polarization tracking system needs to be up and running. It is assumed that automatic focusing is not implemented in this phase. Options for this can be tested with the pilot setup.

6.3. Work packages for phase II

Software for this phase should have been written in the middle of 2004. A serial line connection, or emulation thereof, between the SMA control computer and the JCMT control should be established. The JCMT should also have a polarization rotator in the RxA3 beam, which is programmed to deliver the same rotation as the SMA receivers. The SMA should have adopted several JCMT requirements in their control and processing with more than 8 stations should be possible.

The following tasks are identified, following the numbering of section 3:

6.3.1. Where to go

The point of connection remains in the cabin.

6.3.2. Fibres

No action in phase II

6.3.3. Fibre interface box

No action in phase II

6.3.4. Phase lock system

No action in phase II

6.3.5. Receiver 230 GH

No action in phase II

6.3.6. Gunn 230 GHz
No action in phase II

6.3.7. Receiver 345 GHz
No action in phase II

6.3.8. Gunn 345 GHz
No action in phase II.

6.3.9. Receiver 690 GHz
No action in phase II.

6.3.10. Polarizer
1. The heterodyne $\lambda/2$ phase rotator must be mounted in the RxA3 beam.
2. Software to rotate the cabin polarization beam as if it were on an SMA Nasmyth needs to be installed and tested

6.3.11. SMA antenna computer
1. Needs to be outfitted with a communication link to carry serial information from it to the local JCMT control.

6.3.12. Software
1. An interface layer needs to be implemented that translates SMA antenna control commands to serial ASCII commands. Return values must find their way back to the reflective memory status. This work involves SMA personnel to help accessing the code on the SMA computer. A design for this is to be established in the first half of 2004.
2. After phase I is completed this software can be tested on the antenna computer.
3. Test telescope pointing with SMA control.
4. Test load calibration.
5. Test pointing and inserting pointing updates into the JCMT control.

6.3.13. WVR
No action in phase II.

6.3.14. JCMT parameters at SMA control
1. Walsh functions for the additional eSMA antennas
2. Slewing rates and cable wraps of JCMT must be inserted in eSMA operations.
3. System temperature calibration must allow for JCMT data.
4. Pointing procedures must be adopted for using the JCMT.
5. Output product must reflect JCMT data properly

6.4. Milestones

The work for phase II is inserted in the Gantt chart below (Figure 1). It can be seen that a system can be ready for first image and pilot observations at 230 GHz can be realized in the first quarter of 2005. After the first fringes the success depends mostly on software issues, both at the JCMT and SMA side.

A number of milestones can be identified; most of these are just the successful completion of the mentioned testing.

7. Resources

The current budget for the eSMA amounts to 220 k$. About 65% of this will be spend on hardware to interface to the SMA and possibly software efforts from the SMA side. The remaining budget is reserved for receiver upgrades, a possible new LO for RxA3 and contingency. This covers only the upgrade of RxA3, not RxW and certainly not RxB3. This budget does not include any extra manpower in engineering, software or user support. Here it is considered whether there is sufficient in-house manpower to carry out this program.

A breakdown of all tasks over the entire duration of the project is presented in Figure 2, colours have been used to discriminate between tasks that require different expertise. This chart assumes that all resources (manpower) to carry out the project are made available. It also ignores the fact that the arrival of SCUBA2 will imply many months of downtime sometime in 2005. The ideal plan in Figure 2 leads to first fringes with RxA3 in 2004. In early 2005 it seems possible to get to a first image with the eSMA at 230 GHz, showing that the JCMT can work as an element in the array. There is a possibility of doing some pilot observing at 230 GHz that semester. At that time HARP will need to be installed at the JCMT and the interface for eSMA to be moved to the Nasmyth. It should then be possible to have an eSMA imaging test using HARP by the end of 2005 in the 345 GHz band. This could then be advertised for pilot projects (at 345 only) for semester 06A, depending on the SCUBA2 construction work. By 06B it may be possible to connect also RxA3 again, and first tests with RxW are possible then, if 690 GHz is positively evaluated and budget is available. This schedule depends critically on a number of external factors. Of these the most critical is probably the commissioning of ACSIS and HARP.

It seems that the expertise for all the tasks is present at the JAC. The possible exception could be the evaluation of the interferometric data. This requires outside help, possibly from the SMA, possibly from other specialists in the JCMT community.

However, it is very clear that the engineering department is overloaded with the arrival of WFC on UKIRT, followed by ACSIS on the JCMT and later HARP. It seems that the most critical in this respect are mechanical engineering tasks (fitting the IF/LO box etc). For this part we cannot see any external contribution being much use. These tasks will need to be prioritized with respect to other local duties at the JAC.

There are a number of software issues to be resolved. These seem in general similar to the interfacing problems for HARP. Except for the interface definitions, which have to be done in cooperation with the SMA, there seem to be adequate resources in house for these.

There is considerable work required to upgrade receiver A3. This could be fitted in with the work schedule for Brian Force. He could also work on the Gunn for RxA3 if necessary.

It seems that there is a real need for high-level manpower over viewing the assembly of all the components in the latter half of 2004, as well as supervising the initial testing. There is nothing in this area that could not be done by either Per Friberg or Remo Tilanus, but it is clear that they will not have the time to chase this project on a daily basis and maintain the interface with the SMA.

For the analysis of test data and later user support there is clearly an opportunity for a dedicated post-doc at the JCMT. Such a person could be useful for testing too in early 2005, provided the upgrade remains on schedule.

8. Conclusions

It is possible to outfit the JCMT for operations with the eSMA. The roadmap to 345 GHz operations with HARP and testing with RxA3 requires a temporary setup in the cabin and later a more permanent setup on the Nasmyth platform.

It is not totally clear how difficult it will be to achieve routine observing with cabin systems RxA3, and RxW if desired.

The testing in 2004 requires an irreversible modification of RxA3 IF. This seems under control, but requires ACSIS to be operational in order to maintain 230 GHz capabilities.

The testing also requires a new Gunn oscillator. This could be obtained from the eSMA for testing, but will then not give the same frequency coverage for the JCMT in the long run. A long-term solution for this must be defined soon.

The path to a user system depends on the *commissioning* (not just the arrival) of both HARP and ACSIS. This implies that the user system at 345 GHz could be operational in the middle of 2005 at the earliest. This is already late with respect to the 'ScienceCase'.

There is abundant expertise at the JAC for this process. There is a need for help overseeing the engineering effort in the last half of 2004. Ideally this requires the constant presence of an experienced person at the level of project leader.

Another area in which there is a lack of manpower is the astronomical testing and at a later stage user support. A postdoc dedicated to eSMA testing and user support could provide the necessary manpower and expertise.

ID	Task Name	Resource Names
1	project workpackage definition	astronomer
2	control software interface definition	software
3	**Phase I, toward first fringes**	
4	plan cabin mount (fiber length)	project engineei
5	test and measure fiber	SMA
6	arrival of SMA LO/IF box	SMA
7	fit LO/IF box to cabin	mechanical
8	establish connection antenna computer	project engineei
9	**RxA3 upgrade**	**rf engineer**
10	assess current Dewar layout	rf engineer
11	model new LNA	rf engineer
12	new mount Dewar	rf engineer
13	power supply and cables	rf engineer
14	redesign warm electronic	rf engineer
15	build new electronics	rf engineer
16	ASCIS is operational	JACH
17	upgrade RxA3	rf engineer
18	test RxA3 with ACSIS	rf engineer
19	RxA3 tested complete	rf engineer
20	acquire new Gunn for RxA3	SMA
21	design and fit new mount Gunn	rf engineer
22	outfit RxA3 with Gunn	rf engineer
23	test RxA3 stand-alone	project engineei
24	RxA3 upgraded and compatible Gunn	
25	hook-up RxA3 to SMAcomponents	project engineei
26	established control RxA3 from SMA	
27	insert JCMT position SMA	SMA
28	manual polarizer	project engineei
29	first fringes	astronomer
30	analysis	astronomer
31	**Phase II, first image**	
32	software interface	software
33	install control software	software
34	test telescope control from SMA	astronomer
35	test load control	astronomer
36	test pointing with interferometer	astronomer
37	insert automatic polarizer	project engineei
38	SMA ready for 10 telescopes	
39	full track test with 8-10 telescopes	
40	analysis and verification	astronomer
41	230 GHz ready for pilot projects	

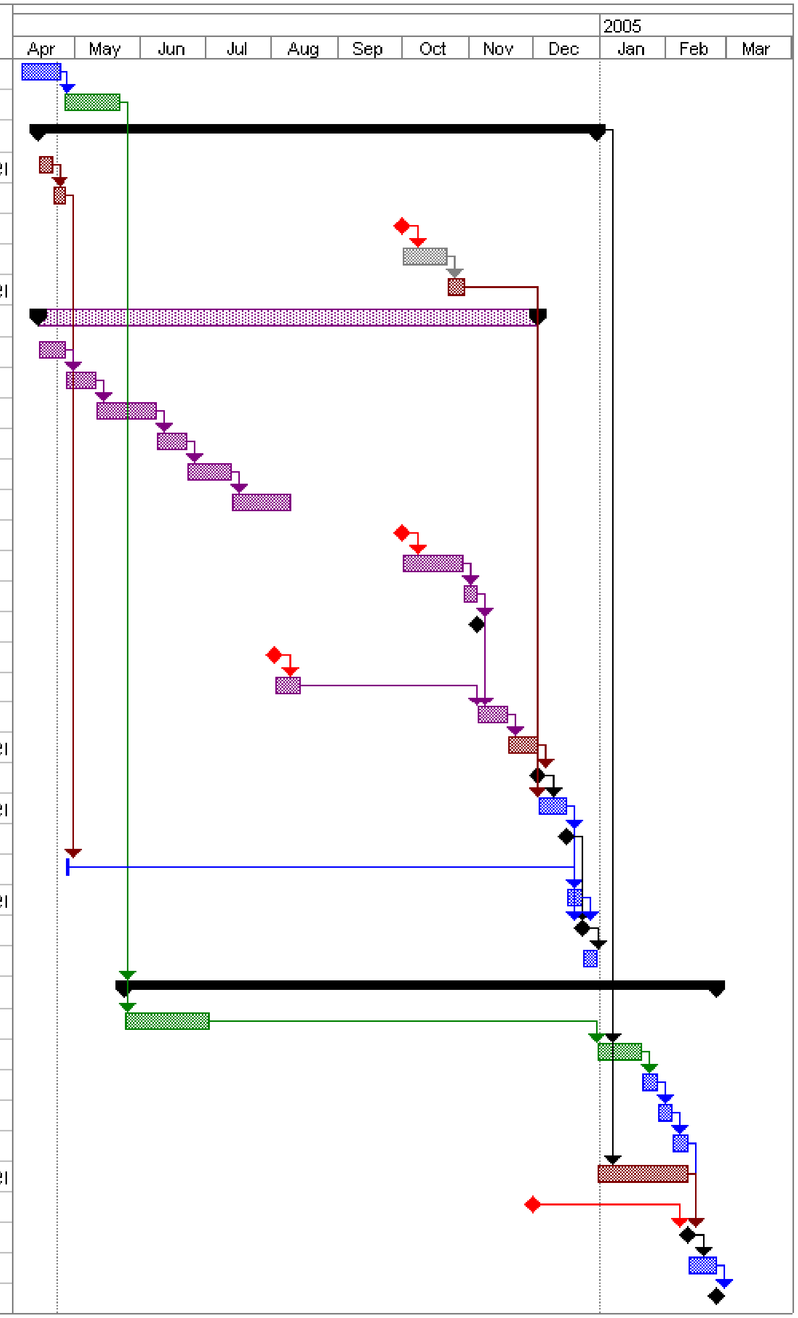

Figure 1; Gantt chart with focus on phase I & II. Note that this timeline assumes all necessary manpower is made available.

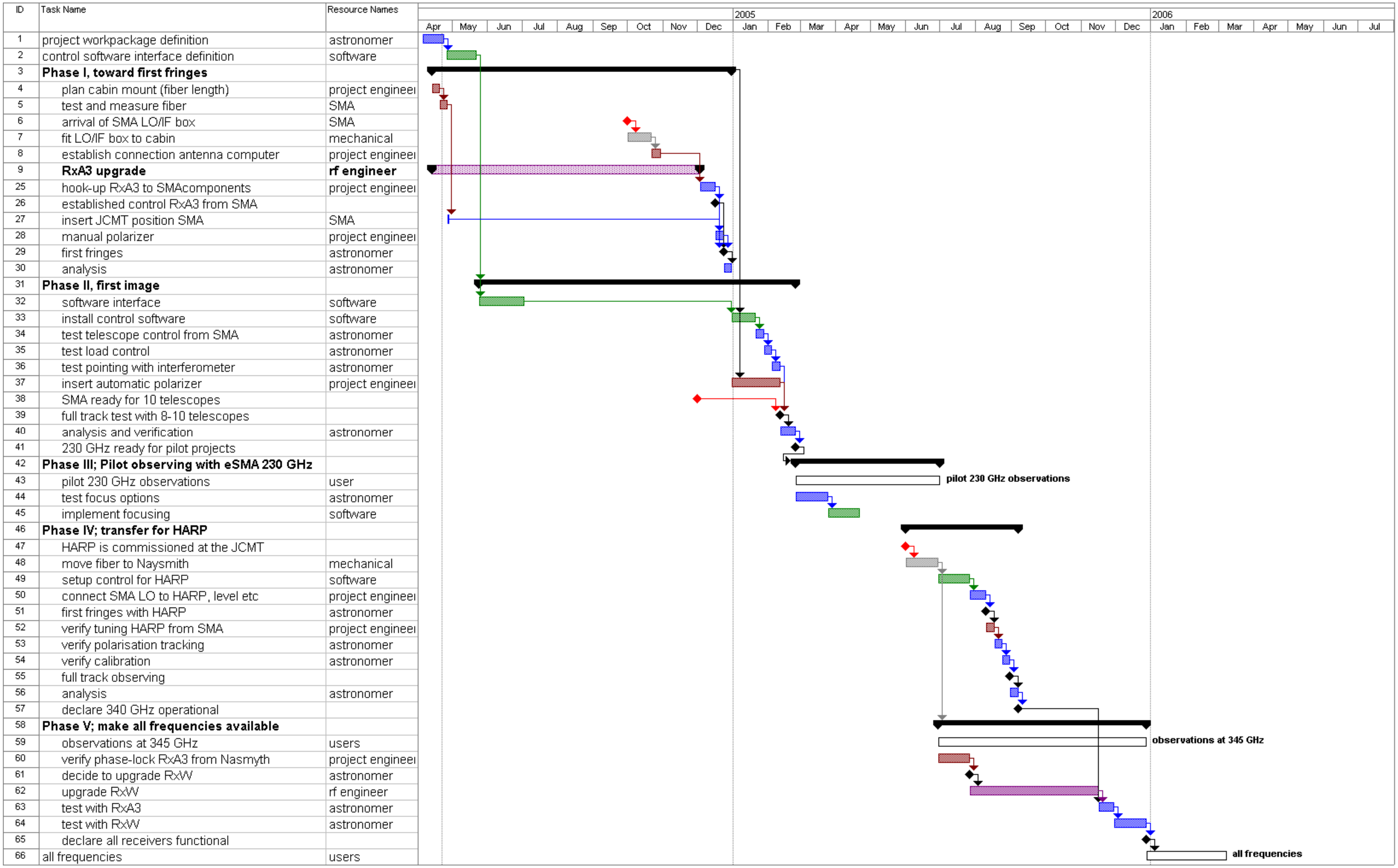

Figure 2; Entire eSMA upgrade timeline, this assumes all required manpower is made available and does not take into account downtime for SCUBA2 construction work yet.