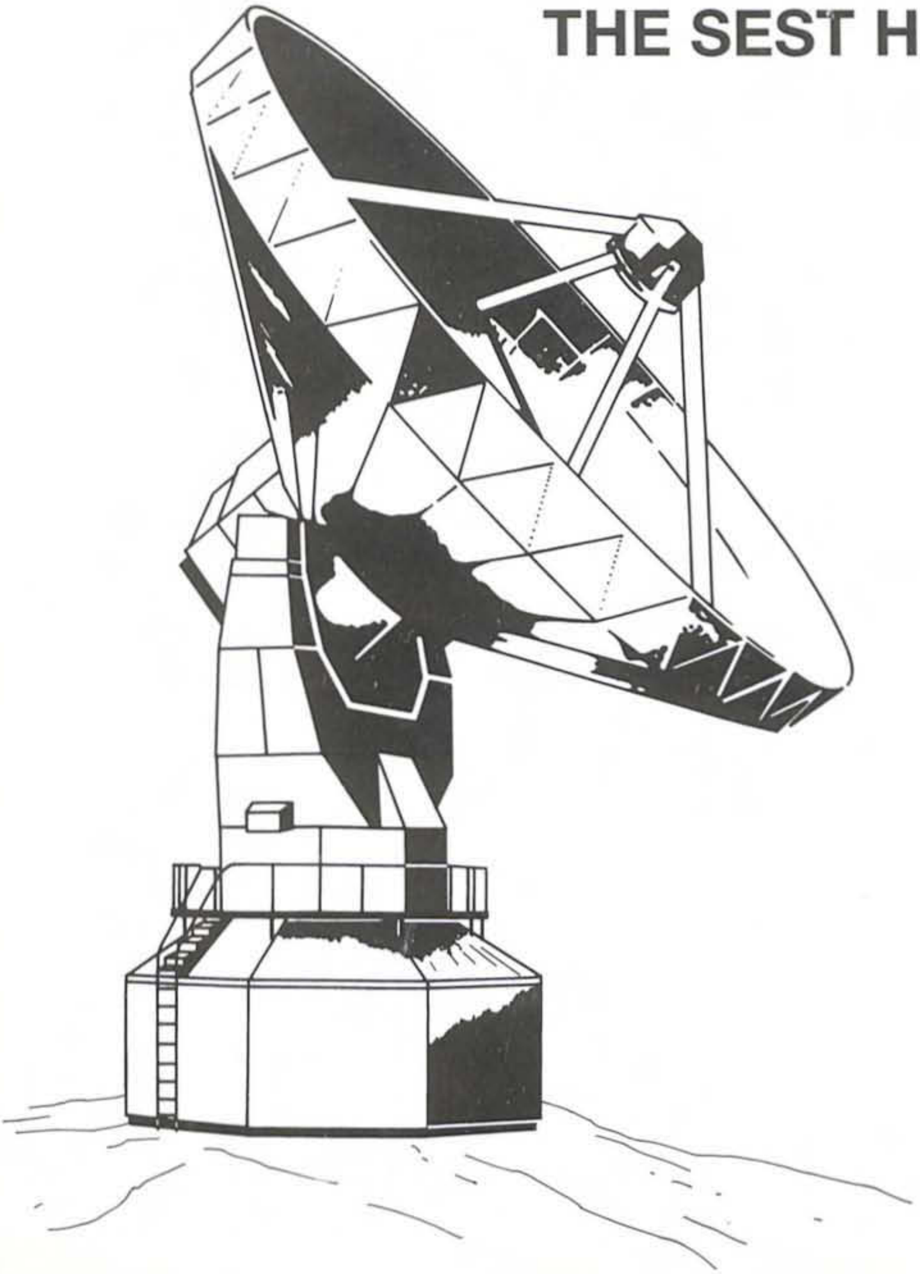
EUROPEAN SOUTHERN OBSERVATORY

OPERATING MANUAL

No. 19 – August 1993

THE SEST HANDBOOK



THE SEST HANDBOOK

August 15, 1993, Version 1.0

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Chapter 1

Introduction

1.1 Background

The Swedish–ESO Submillimetre Telescope, acronym SEST, is a 15 m diameter radio telescope, which operates in the frequency range 80 - 365 GHz. It was built in 1987 on the ESO site of La Silla, in the Chilean Andes, at an altitude of 2300 m.

The telescope, as its name implies, has been built on behalf of the Swedish Natural Science Research Council (NFR) and the European Southern Observatory (ESO). It is presently the only large millimetre/submillimetre telescope in the southern hemisphere.

On the Swedish side SEST is operated by the Swedish National Facility for Radio Astronomy, Onsala Space Observatory at Chalmers University of Technology, which is responsible for the receivers and the computer software. ESO is responsible for the mechanical, and computer hardware maintenance as well as maintenance of the control building.

1.2 Proposals

The observing time is split equally between Sweden and ESO on a month by month basis. From the point of view of proposals for observing time, the year is divided into two semesters: April 1 - September 30 and October 1 - May 31. Deadlines for submission of proposals are October 15 and April 15, respectively. There are two programme committees; a Swedish committee assesses proposals for Swedish time and proposals for ESO time are dealt with by the ESO OPC (Observing Programmes Committee). Observing proposals for Swedish time should be submitted to:

Prof. R.S. Booth

Onsala Space Oservatory, S-439 92 Onsala, Sweden

and for ESO time to:

Section Visiting Astronomers, ESO,
Karl-Schwarzschild-Strasse 2, D-8046 Garching, Germany

Special proposal forms are used, copies of which can be ordered from the addresses above.
Note that because of the warm and relatively humid conditions during the Chilean summer, use of the highest frequency receivers is restricted to the winter months (June through September).

1.3 Observations

The observing sytems at SEST are designed to be user friendly and failsafe such that the observer can perform his/her own observations, and even tune the receivers, after a short initial period of instruction. The observer should arrive one day before the observations for preparations. At this point the astronomer- on-duty will assign a computer account to the observer and help him or her to set up observing files. He will also be prepared to discuss the best way to perform the observations. When the observations commence, he will introduce the visitor to the observing procedures and on receiver tuning. Although observers conduct their own observations, the duty astronomer is always available to help solve problems and operator assistance is available during night time.

At SEST basic data reduction programs are available for simple on-line analysis. They are intended to be used by the observer as a guide for the preparation of the continuing observations. However, the final data reduction should be done at the home institute of the observer.

At the end of an observing run the data is written to a standard 9 track computer tape in FITS format for transportation.

A list of pointing and calibration sources are given at the end of this manual. In the SEST control room there is a binder containing all measured spectra of the calibration sources.

1.4 Communication with SEST

Communication with SEST should be done through the Scientist–in–charge,
Lars-Åke Nyman
email address: sest@eso.org
FAX: +56 2 695 4263

1.5 The purpose of this manual

This manual gives a short description of SEST with details of the receivers and the standard observing procedures. It is intended as a guide to be of assistance in writing proposals and in the planning of observations with SEST. It does not however contain a full description of all SEST commands and procedures which are to be found in a complete manual at the telescope.

Chapter 2

Technical description

2.1 The telescope

The 15 m diameter SEST was designed by IRAM (Institut de Radio Astronomie Millimétrique) and is similar to the telescopes built for their millimeter interferometer on Plateau de Bure, but it stands on a fixed base. It was built by IRAM under contract, with main engineering subcontractors in the French and German industry.

The telescope stands in the open air and does not have a radome or other protective enclosure. The structure is therefore strong enough to permit observations in winds up to 14 ms^{-1} (survival wind speed - 56 ms^{-1}) and its thermal propoerties are such that temperature gradients due to differential solar heating across the structure do not affect the pointing.

SEST is a Cassegrain antenna with a rather low (3.5%) surface blockage. The main reflector consists of 176 panels, each formed from aluminium honeycomb material between carbon fibre reinforced plastic skins. The reflector surface consists of a layer of aluminium, protected by a thin transparent teflon sheet, bonded to the outer surface. The rms deviation of the individual panels from their prescribed shapes is typically 12 μm. Every panel is provided with five support points each of which may be adjusted by remotely controlled motors, which makes it possible to adjust the total reflector surface. In this way, the reflector surface has been set with an overall rms deviation from the ideal paraboloid (in the zenith pointing position) of about 70 μm. Future holographic measurements and subsequent adjustments of the surface are expected to reduce this rms deviation to around 50 microns.

The telescope is designed according to the homology principle. The subreflector vertical tilt and position are remotely controlled and programmed to compensate for the gravity deformation of the main reflector and to adjust the focus of the telescope.

A full description of the telescope and original observing sytems has been published by Booth et al, Astron. Astrophys., 1989, 216, 315, and an update

Table 2.1: SEST Parameters (From October, 1990)

Position:		
longitude	70d43'48" (W)	
latitude	-29d15'36"	
Diameter	15 *m*	
Surface accuracy	70 μm (rms)	
Half power beamwidth (FWHM):		
86 GHz	57"	
115 GHz	45"	
230 GHz	23"	
346 GHz	15"	
Main beam efficiency:		
86 GHz	0.75	
115 GHz	0.70	
230 GHz	0.60	
346 GHz	0.25	
Aperture efficiency:		
86 GHz	0.62	(25 Jy/K)
115 GHz	0.58	(27 Jy/K)
230 GHz	0.38	(41 Jy/K)
346 GHz	0.16	(98 Jy/K)
Moon efficiency:		
100 GHz	0.90	
230 GHz	0.90	
Pointing accuracy	3" rms in Az and El	
Max operational wind	14 m/s	
Sun constraint	50°	

was given by Nyman and Booth at the 29th Liége Colloquium, ESA SP-314 (December, 1990).

Because of the danger of severe overheating of the subreflector region by reflected sunlight from the highly reflecting telescope surface, SEST is constrained never to track within 50° of the sun.

The main parameters of the telescope are given in Table 2.1.

2.2 Receivers

2.2.1 Heterodyne receivers

SEST is equipped with dual polarization Schottky receivers covering the 3 mm atmospheric window, and single polarization SIS receivers covering the 1.3 and 0.8 mm windows. The Schottky mixers are cooled to 15 K by a closed cycle helium refrigerator and the SIS mixers are cooled to 4 K by liquid Helium. The IF bandwidth for all receivers is 1 GHz, and one of the 3mm Schottky receivers can be used simultaneosly with the 1.3 mm SIS receiver.

During 1994 the 3 mm Schottky receivers will be replaced by SIS receivers covering the 3 and 2 mm atmospheric windows.

The receivers are tuned under computer control from the control room. With some experience the observer is able to tune without staff assistance whenever he or she wants to. A change of frequency normally takes 5 to 10 minutes.

Quasi–optics

Fig. 2.1 illustrates the optical arrangement at the secondary focus. A chopper wheel switches between two beams symmetrically displaced in azimuth to each side of the telescope axis, the beam separation being 11'37" on the sky. For narrower beam separation, 2'27", the flip mirror in front of the chopper wheel can be flipped through 90° so that both beams are offset to the same side of the telescope axis, which should allow optimum cancellation of atmospheric fluctuations when observing unresolved sources. With the selection mirror one can decide which receiver to use.

The chopper wheel speed is phase locked to give a beam switching speed of 6 Hz. The total blanking time per cycle is less than 10%. The chopper can also be stopped and used to switch between the signal and reference beams on command.

For calibration purposes, the reference and signal beams can be focused onto two temperature controlled loads, the hot load (approximately 322 K), and the cold load (approximately 275 K). A harmonic mixer is used to inject a synthesized test signal into the signal beam through the right load mirror, thus being common for both receivers. This test signal can be set for both sidebands and is useful for verifying that the receiver is tuned to the correct frequency and single sideband (SSB) operation.

3 mm receiver

The 3 mm Schottky receiver can be tuned between 80 and 116 GHz. Fig 2.2 shows the receiver temperature as function of frequency. The two dual polarization mixers have similar receiver temperatures between 100 and 110 GHz,

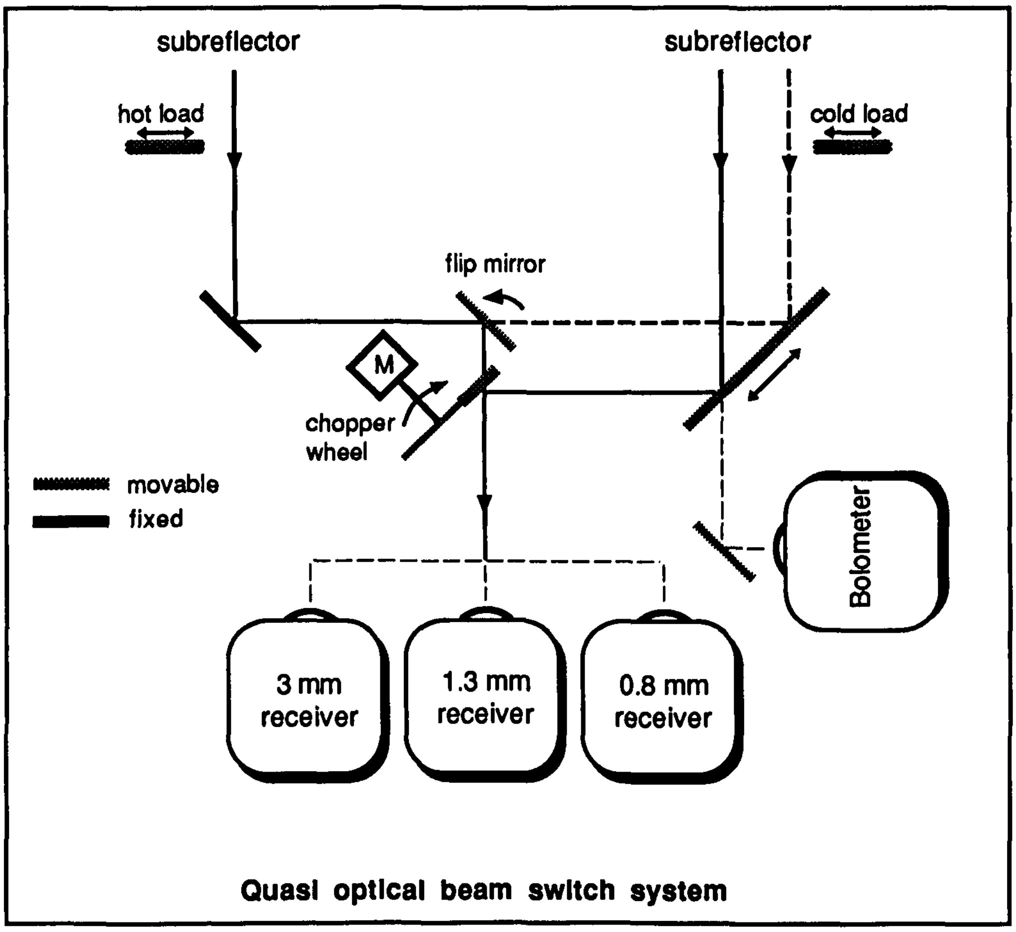

Figure 2.1: Quasi–optics

while Mixer A is better at frequencies higher than 110 GHz and Mixer B at frequencies below 100 GHz.

For true single sideband (SSB) operation the mixer backshorts can be set to suppress the image sideband while maintaining a match at the signal frequency. The image band rejection is typically about 20 dB. For continuum observations the backshort can be set for double sideband (DSB) operation. The Local Oscillator (LO) signal is generated by a phase locked Gunn oscillator. The IF signals at 4 GHz are amplified by cooled HEMT amplifiers. The IF bandwidth is 1 GHz.

1.3 mm receiver

The 1.3 mm SIS receiver is on indefinite loan from the Center for Astrophysics, Cambridge MA. It can be tuned between 215 and 270 GHz. Fig 2.2 shows the receiver temperature as function of frequency.

The LO signal is generated by a combination of a phase-locked Gunn oscillator operating at $\sim$ 75 GHz followed by a frequency tripler. In this receiver the mixer is operated double sideband and a SSB diplexer is used to reject the image band. The image frequency beam is terminated in an absorbing load at 15 K. The image band rejection is typically about 20 dB. The IF signal at 4 GHz is amplified by a cooled HEMT amplifier. The IF bandwidth is 1 GHz.

0.8 mm receiver

The 0.8 mm SIS receiver can be tuned between 320 and 360 GHz. Fig 2.2 shows the receiver temperature as function of frequency.

This receiver is similar to the 1.3 mm receiver: the LO signal is generated by a Gunn oscillator and a frequency tripler, the sideband rejection is done with a SSB diplexer, and the IF signal at 4 GHz is amplified by a cooled HEMT amplifier with 1 GHz bandwidth.

2.2.3 1.3 mm Bolometer

The SEST bolometer was designed by Ernst Kreysa at MPIfr, Bonn. A similar bolometer is described in Kreysa (1990, "From Ground–Based to Space–Borne Sub–mm Astronomy", Liege, Belgium, ESA SP–314, p. 265). The bolometer has a center frequency of 236 GHz (1.27 mm) and a bandwidth of about 50 GHz. The sensitivity is 200 $\mathrm{mJys^{-1/2}beam^{-1}}$ (in one second a one sigma noise of 200 mJy is reached). It consists of a Germanium element inside a ^{3}He cryostat cooled to about 0.3 K. The hold time is about 36 h, but for operational reasons the recycling of the ^{3}He and and refill of ^{4}He and Nitrogen is done every 24 h, a process that takes about 4 h.

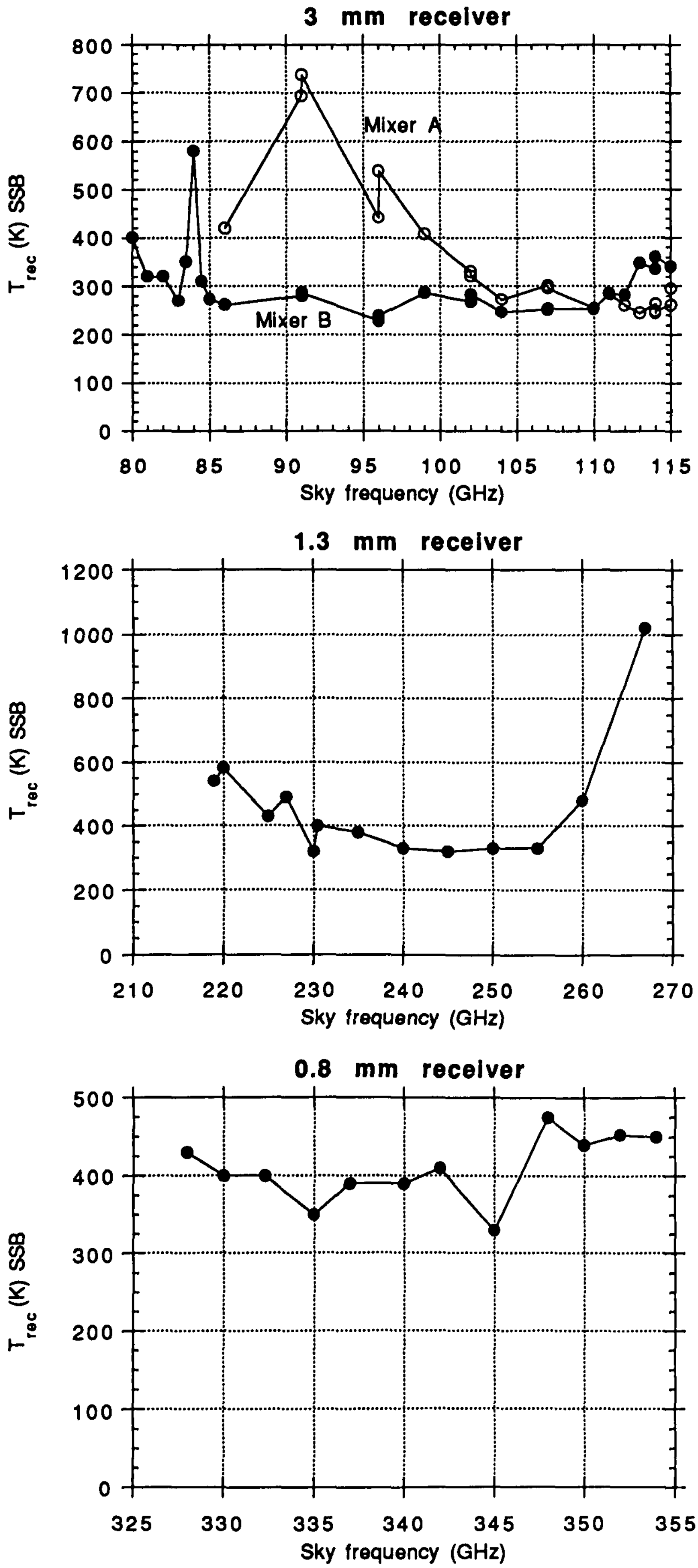

Figure 2.2: Receiver temperatures

Table 2.2: Spectrometer characteristics

	HRS	LRS1	LRS2
Total bandwidth	86 MHz	995 MHz	1086 MHz
Number of channels	2000	1440	1600
Channel separation	43 kHz	0.69 MHz	0.68 MHz
Resolution	80 kHz	1.4 MHz	1.4 MHz
Noise bandwidth/channel	105 kHz	1.8 MHz	1.8 MHz

Bolometer optics

The bolometer is accessed by removing a remotely controlled mirror in the quasi-optical arrangement (see Fig 2.1). It has its own focal plane chopping mirror. An ecosorb load can be inserted in one of the beams for calibration purposes. The beam separation is nominally 70", but can be adjusted to 120". In case of bad weather (unstable atmosphere) during bolometer observations it is possible to switch to spectral line observations within 5 to 10 minutes.

2.3 Spectrometers

Three Acousto Optical Spectrometers (AOS:s) are used as backends for spectral line and sometimes continuum observations. These AOS:s were built at the University of Cologne and their general design characteristics have been described in Schieder et al. (1989, Experimental Astronomy 1, p. 101).

Two of the AOS's cover a wide band (1 GHz), with lower resolution (LRS = Low Resolution Spectrometer), the third one covers a narrow band (86 GHz), but has a higher resolution (HRS = High Resolution Spectrometer). Their characteristics are described in Table 2.2.

2.4 Combinations of receivers and spectrometers

It is possible to observe with two spectrometers simultaneously. For single receiver operation the HRS and one LRS can be used simultaneously and the HRS can be placed anywhere within the band of the LRS. During dual receiver operation the two polarization channels of the 3 mm receiver can be used at the same time or one of the 3 mm polarization channels can be used together with the 1.3 mm receiver. In this case the two LRS's can be used simultaneously to cover as large a band as possible for each receiver, but at lower resolution. To obtain higher resolution it is possible to split the HRS into two parts and connect each part to one receiver. The HRS then has a bandwidth of 43 MHz per receiver. Also one of the LRS's can be split into two parts (2 x 500 MHz) and each part can be connected to one receiver.

Note that the 0.8 mm receiver can not be used simultaneously with another receiver.

2.5 The telescope and instrument control system

The telescope and associated instrumentation are controlled by two networked minicomputers: a Hewlett Packard 1000/A900 and an HP1000/A600 running under the operating system RTE–A. The A900, the main computer, is used for general purpose instrument control and data reduction. The A600 (a smaller version of the A900) is dedicated to data acquisition from the spectrometers. The two computers are linked by ethernet.

The telescope servo loops for azimuth and elevation tracking are closed by a 16 bit microprocessor. The microprocessor system also performs other functions, such as initializing the encoders, monitoring limit sensors, etc.

Weather data is transmitted from the La Silla weather station, located on the northern side of the peak and is recorded by the A900. A local weather station, situated about 20 m north of the telescope, also supplies wind, temperature, and humidity information.

In case of a power failure, the Uninterrupted Power Supply unit (UPS), supplies power to the computer, to its terminals and to the telescope for a limited time. Thus, the observations are not stopped because of a power failure.

Chapter 3

Observations

3.1 Spectral line observations

3.1.1 Observational methods

Several observing methods are available at SEST. The choice of a certain method depends on the source size, line width, expected line strength etc. We will here desribe the methods used at SEST.

Beam switching

Beam switching at SEST is done with a focal plane chopper wheel that rotates with a frequency of 6 Hz. The beam throw is either 11'37" or 2'27" in azimuth (see Section 2.2.1). In dual beam switching the source is first placed in the signal beam and then in the reference beam. This produces a pair of spectra that are subtracted from each other to produce flat baselines. Antenna movements, the readout time of the spectrometers, etc. takes about 20 s per spectrum. Using short integration times will therefore produce a large overhead. For observations consisting of many individual spectra taken with an integration time of e.g. 120 s, typically one third of the time is spent ON source, one third OFF source and one third is overhead. In this case an integration ON source of 1200 s needs a total observing time of 3600 s.

Beam switching should be used for observations of sources with a small spatial extent (smaller than the beam throw), especially if the lines are wide and weak, e.g. external galaxies. With this method it is possible to obtain continuum levels using the offset from the zero level of the baseline.

Position switching

In position switch mode the whole telescope is moved between an ON and a definable OFF position. A spectrum is produced by taking ON–OFF. The OFF position should be free from emission. It is possible to define the OFF position relative to the ON position, or in absolute coordinates. The quality of the baseline depends on the distance between the ON and the OFF position, the integration time on each position, and the stability of the atmosphere. The overhead time is similar to that of beam switching (about 20 s per spectrum).

Position switching should be used for extended sources that can not be observed using beam switching or sources with wide or multiple lines that can not be observed with frequency switching (see below). The Galactic Centre region is an example of such a source.

Frequency switching

In the frequency switch mode the telescope is tracking the ON position and the switching is done by changing the frequency of the local oscillator. If the frequency throw is less than the bandwidth of the spectrometer a single spectral line produces both a positive and a negative component in one spectrum displaced by the frequency throw. The two components can later be added together. Thus it is an efficient method because both the ON and OFF time is spent on the source. At SEST frequency throws up to 60 MHz have been used, but it is recommended to use throws less than 30 MHz. The baselines are of varying quality depending on the frequency throw and to some extent on the observing frequency. With the SEST 3 mm receiver it is possible to balance the mixer currents at the two frequencies by using the settings of the other mixer. At frequencies between 100 and 115 GHz this produces fairly flat baselines.

Frequency switching should be used for extended sources with fairly strong, narrow lines, e.g. molecular clouds. The frequency throw has to be chosen such that it is larger than the line width of the source, or in case of multiple line components, larger than the separation between the components. With frequency switching at the CO frequencies the telluric (mesospheric) CO line is not cancelled and appears in the spectrum. Its intensity varies with the time of the year, typical intensities are 1 K in the CO(1-0) line and 4 K in the CO(2-1) line. Sometimes this line can interfere with CO lines from the observed source. The velocity of the mesospheric CO line relative to the LSR varies with the direction on the sky and the time of the year. It is usually possible to choose a time of the year when the line does not interfere with the CO lines in a source. Otherwise it is also possible to take a reference scan in an OFF position and remove the mesospheric contamination during later data reduction.

Mapping

At SEST there is a standard routine to perform rectangular maps, strip maps, and five point maps (it can also map from a list of grid positions supplied by the observer). The maps can be tilted by giving a position angle. All observing methods described above can be used for mapping. For position switching a relative or absolute reference position can be given and several ON spectra can use one OFF spectrum.

As already mentioned it takes about 20 s from the time an integration is finished in one position until the next integration starts (this is due to AOS readout time, telescope movement, etc). Therefore mapping with short integration times/position is fairly inefficient.

3.1.2 Observing time estimate

This section will show how to roughly estimate the expected rms noise in spectra taken with SEST.

The equivalent system temperature outside the atmosphere is calculated from the expression:

$$T_{sys} = [T_{rec} + T_{atm}(1 - e^{-\tau_o/\sin(El)})]e^{\tau_o/\sin(El)} \qquad (3.1)$$

where T_{rec} is the receiver temperature, T_{atm} is the integrated physical atmospheric temperature (normally about 290 K), τ_o is the atmospheric zenith opacity, and El the elevation of the source. Table 3.1 lists typical values of the atmospheric zenith opacity at La Silla. This is only a rough estimate, but good enough for most applications. The fact that the telescope also picks up some signal from the ground is not taken into account.

Table 3.1: Typical zenith opacities at La Silla during good conditions

ν(GHz)	86	115	230	345
τ_o	0.05	0.30	0.1-0.3	0.3-0.6

The rms noise in the spectrum is calculated from:

$$\Delta T = \frac{T_{sys}C}{\sqrt{Bt_{int}}} \qquad (3.2)$$

where C is a factor depending on the observing method used, B is the noise bandwidth/channel of the spectrometer, and t_{int} the integration time. C is equal to $\sqrt{2}$ for beam switching and position switching (because noise is added when the OFF spectrum is subtracted from the ON spectrum) and 1 for frequency switching.

We will now calculate which integration time is needed to obtain an rms noise of 0.1 K with the HRS at 115 GHz using the different observing methods. The elevation of the source will be assumed to be 60°.

The equivalent system temperature outside the atmosphere will be calculated first. The zenith opacity at 115 GHz is about 0.3 (Table 3.1). The receiver temperature as function of frequency is shown in Fig. 2.2 and is about 300 K at 115 GHz. Using these values in equation 3.1 we get

$$T_{sys} = [300 + 290(1 - e^{-0.3/\sin(60)})]e^{0.3/\sin(60)} = 544\,K$$

Equation 3.2 can be rewritten:

$$t_{int} = \left(\frac{T_{sys}C}{\Delta T}\right)^2 \frac{1}{B} \tag{3.3}$$

The noise bandwidth/channel is given in Table 2.2 and is 105 kHz for the HRS.

For beam switching and position switching $C = \sqrt{2}$, and we want to reach $\Delta T = 0.1K$. This gives $t_{int} = 563\,s$. This value has to be multiplied by a factor depending on the time spent in the OFF position and the overhead time (a factor of 3 that includes the time spent off source, telescope movements and calibrations) to obtain the real time necessary for the observation. The result is $1689\,s = 28\,min$.

For frequency switching $C = 1$ which gives $t_{int} = 281\,s$. This value has to be multiplied with a factor of 2.2 that includes time spent at the off frequency, calibrations etc. The result is $620\,s = 10\,min$.

The estimated rms noise values should of course be compared with the expected signal intensity. The main beam and moon efficiencies of the SEST at 115 GHz are 0.7 and 0.9, respectively (see Table 2.1). Thus a CO(1-0) line with a brightness temperature of 10 K would give an intensity of $10 \cdot 0.7 = 7\,K$ if the source just fills the main beam or $10 \cdot 0.9 = 9\,K$ if the source is extended.

3.1.3 Pointing strategy

The pointing accuracy of SEST is about 3" rms in azimuth and elevation. This is good enough for most observations at 3 mm, but not at 1.3 mm.

Unfortunately there are not many bright, pointlike sources in the southern sky that can be used as pointing sources. A list of SiO masers, CO sources (circumstellar envelopes), and quasars used for SEST pointing is given in Appendix B. Mars, Jupiter, Saturn, and Uranus can also be used, if they are outside the Sun constraint.

In case a pointing source is within 10° to 15° from the observed source the obtained pointing offsets can be used, and the pointing should be checked at least every 3h. If there is no nearby pointing source the pointing should be checked 2 to 3 times during an observing shift, and if the offsets are within 10", they should be reset to zero.

3.1.4 Calibration and calibration sources

The intensity calibration is done with the chopper wheel method, and the intensity scale of a spectrum is given in T_A^*. The second order chopper wheel correction term (see Ulich and Haas,1976, ApJS 30, 247) is also calculated and applied in the AOS software. To convert the intensity scale to main beam brightness temperatures, the T_A^* intensities should be divided by the main beam efficiencies given in Table 2.1.

The internal SEST intensity calibration is very stable. A set of sources are observed occasionally in various molecular lines, and the intensities are reproducable within 10%. The SEST intensities have been compared with the intensities obtained with the IRAM 30m telescope for various sources, and for a few sources with the Bell Lab's and FCRAO telescopes. The intensities are reproducable within 20% to 30%.

A set of calibration sources is given in the Appendix. A binder with calibration spectra of these sources can be found in the SEST control room.

The AOSs have a non linear frequency scale. At SEST the frequency axis is automatically linearized by applying a second order polynomial that is updated several times per year. There may also be a linear drift in the frequency axis due to e.g. temperature changes inside the AOS. At each calibration a frequency comb (a set of narrow lines with well defined frequencies) is applied, and the spectra are automatically corrected for drifts.

3.1.5 Velocity systems

It is possible to observe in the LSR, heliocentric, geocentric, and topocentric velocity systems. Different conventions for the doppler correction can also be given; either relativistic, radio, or optical. The observer has to know which convention that was used to determine the velocity of the source. For a given radial velocity the calculated sky frequency can be different depending on the convention used.

Using relativistic doppler correction the sky frequency is given by

$$f_{sky} = f_{rest}\sqrt{\frac{1-\frac{v}{c}}{1+\frac{v}{c}}} \tag{3.4}$$

The radio convention gives the correct sky frequency for a velocity obtained through a radio measurement (e.g. HI) and uses the form

$$f_{sky} = f_{rest}(1-\frac{v}{c}) \tag{3.5}$$

The optical convention is the correct one for a velocity obtained through an optical redshift by $v = c \cdot z$ and uses the form

$$f_{sky} = f_{rest}/(1+\frac{v}{c}) \tag{3.6}$$

where f_{sky} is the sky frequency, f_{rest} the molecular rest frequency, v the radial velocity of the source, and c the speed of light. Table 3.2 gives the difference in sky frequency between the various methods at a few velocities. A rest frequency of 115 GHz was used. At velocities > 1000 kms^{-1} it starts to become important to know in which convention the radial velocity of a source is given.

Table 3.2: Sky frequency calculations, $f_{rest} = 115\,GHz$

v kms^{-1}	f_{sky}(rel) – f_{sky}(radio) MHz	f_{sky}(rel) – f_{sky}(optical) MHz
100	0.006	–0.006
1000	0.64	–0.64
5000	15.7	–15.7
10000	61.8	–61.8
20000	239.3	–239.9

3.2 Bolometer observations

3.2.1 Observational methods

Only beam switching is used for bolometer observations. The beam throw is nominally 70", but can be adjusted up to 120". Point sources can be observed in the ON–OFF mode and more extended sources can be mapped. Mapping is done in a dual-beam scanning mode, and the data is later restored to an equivalent single-beam observation (using the NOD2 package by G. Haslam). A "quick-look" data reduction facility for bolometer maps is installed on a PC 486 at SEST. The final data reduction should however be done at the home institute of the observer.

A bolometer observation typically consists of a skydip to obtain the atmospheric opacity, a pointing and a focusing on a bright pointing source, followed by ON–OFF or mapping observations. In good weather it is only necessary to do a skydip every 3–4h, otherwise more often. A calibrator source should be observed every shift.

3.2.2 Time estimate for ON-OFF observations

The sensitivity of the bolometer is nominally 200 mJy s$^{-1/2}$ beam^{-1}, i.e. in 1 sec of integration an rms of 200 mJy is achieved. Only half of the time is spent on the source and there is some overhead due to telescope movements etc. so the estimated integration time on source should be multiplied by a factor of 3 to take care of this. During unstable atmospheric conditions, however, the observations are limited not by detector noise but by atmospheric fluctuations ("sky noise"), and it may either be impossible to reach the estimated sensitivity or it may take a considerably longer time.

3.2.3 Pointing and calibration

Because of the high sensitivity of the bolometer, many more pointing sources are available compared with spectral line observations. A list of pointing sources is given in Appendix B. In most cases it is possible to find a nearby pointing source.

Uranus is used as a primary flux calibrator, and other planets and a dust source in Orion as secondary calibrators.

For point sources it is necessary to correct for the gain–elevation characteristics of the SEST at 1.3 mm wavelength. The correction factor has been determined from a fit to data obtained of Uranus, and it has the following form:

$$\mathrm{CF} = 1/(\cos^2(\mathrm{El} - 64.8°) + 0.31\sin^2(\mathrm{El} - 64.8°))$$

The obtained intensities should be muliplied with CF.

3.3 Export Tape Formats and Backups

A standard computer tape drive is available to store data on tape. The tape densities are 800, 1600, or 6250 bpi. Spectral line data is normally transported in FITS format. The SEST FITS header is listed in Appendix D. Tapes can also be written in HP format (FST and TAR).

Continuum (bolometer) scans are written in ASCII format.

The observers are recommended to do a daily backup of their data after each observing shift to avoid data loss in case of a disc crash. When the observations are finished, the data will be backed up on a SEST archive tape which is kept at the telescope for several years.

Chapter 4

SEST observations

4.1 Introduction

This chapter intends to give a quick overview of the most common SEST commands and how to observe with SEST. A more detailed handbook is available in the SEST control room. A brief description of all SEST commands is given in Appendix A.

4.2 Sun avoidance

Due to the possible danger from the sun, you must be aware that you should

NEVER LEAVE THE TELESCOPE UNATTENDED !

4.3 Preparations

There are four accounts assigned for the observers: GUEST1, , ,GUEST4. To each account belongs a directory file with the same name. On these directories, command files, scans, etc. will be saved, and they should only contain one project at a time. The astronomer on duty will prepare an account for you. Use the terminal in the visitor's room. Press the <Break> key and log on using your account (the password is posted on the notice board in the control room). Use the command:

GUESTn>**CONSTRUCT**

to create a start file and a source list. The start file, normally named START.CMD is a command file that sets up general parameters, specifically for your observing run. You should run it at the beginning of each session. The source list, normally named SOURCE.LIST is a catalog file that contains the coordinate system and the names, coordinates and velocities of your sources. Even if you only have one source it is advisable to create a source list.

With CONSTRUCT you can only create new files, not modify existing ones. The most flexible way to create and/or modify command files is to use the HP/1000 editor. If you're not familiar with the editor and you want to use it, ask the SEST staff for an introduction.

Having prepared a source list you can predict the visibility of the sources and plot the results. Load a paper into the plotter, then type:

GUESTn>**PREDICT,SOURCE.LIST**

In principle you are supposed to observe and tune the receivers on your own. The astronomer in duty will give you an introduction and assist you in case of questions and problems. If you arrive early, we recommend you to watch the previous observers, especially when they are tuning the receivers.

4.4 Introduction to SEST commands

The SEST observer will log on under one of the assigned accounts GUEST1 to GUEST4, at the control terminals and will be prompted by GUESTn>. At this point any of the SEST commands may be entered. Commands for the SEST control language are of the form of a keyword followed by a parameter list:

KEYWORD p1,p2,p3,p4, , ,

Most parameters have default values. The commas are optional except where required as space holders, when defaulted and non defaulted parameters are mixed. Keywords or parameters may be entered either in lower or upper case or in a mixture of both. The online information on SEST commands is provided through the DOC command. To read about a command, type:

GUESTn>**DOC,command** e.g
GUESTn>**DOC,PARK** to read about the PARK command

Several commands can be given on one line if they are separated by semicolons. They will be executed one after another, e.g:

GUESTn>**SOURCE ORION ; ONPOS . . . ;VSOURCE,5 ;TRACK**

This string sets the source name to ORION, sets the on position to a point in

Orion, sets the velocity to 5 kms^{-1} and makes the telescope track the source.

A very useful feature is provided by the command stack. Type / (slash) to use it. The last commands are listed. To execute one of these old commands, position the blinking cursor under the command string using the cursor arrow keys and hit <Return>. The old command may also be edited with the screen editing keys before execution. These keys are labeled: <Clear line>, <Clear display>, <Insert line>, <Delete line>, <Insert char> and <Delete char>. The cursor keys must not be used to override characters. Use the <Backspace> key or the space bar for positioning.

It may happen that an executing command needs to be aborted or that you want to enter another SEST command during execution. You may get the system's attention by pressing the <Break> key on the keyboard. The prompt CM> will be displayed. The previous command, started from the GUESTn> prompt will continue to execute, even with the CM> prompt displayed. You may now enter a new command. The new command will be executed once <Return> is pressed. If you get the CM> prompt by mistake, just hit <Return>. An error message, displayed at the bottom of the screen is cleared by pressing <Return>.

4.5 Coordinate and angle specification

The SEST control system supports several coordinate systems. To select the coordinate system you want to work with use the SYSTEM command.

To specify the RA/DEC (1950) coordinate system, type:

GUESTn>**SYSTEM,B1950.0**

To specify the RA/DEC (2000) coordinate system, type:

GUESTn>**SYSTEM,EQU**

To specify galactic coordinates, type:

GUESTn>**SYSTEM,GAL**

The full specification of a coordinate or angle parameter is:

<hrs>h<min>m<sec>s
<deg>d<min>'<sec>"

The numeric fields may be either real or integer. The units are mandatory. Do not use a space between a numeric field and the unit. The order of the units is not important as long as the units are present and come after the numeric field. The following are all valid representations of 23.5d:

23.5d, 23D30', 23.5°00'00", 1.5666h, 1h34m00s

Note that the choice of units has no significance on the coordinate. The above example could represent a coordinate in galactic, horizontal, equatorial coordinates or some other system. The meaning of the coordinate is determined by the currently selected system.

Remember: *If no unit is supplied, arcseconds is default.*

4.6 Start of an observing run

The control terminals LU41 and LU42 in the control room are equivalent and can be used interchangeably (LU=Logical Unit). They are the only terminals that can control the telescope and the observations. Normally, LU41 is used for setting up the system, and for starting integrations, while LU42 is used for tuning. Press <Break> and log on using your account:

BIENVENIDO! **GUESTn**

After pressing <Return>, you have to enter a password which is posted on the notice board. The prompt displayed once you are logged on, shows the the current guest account that is in use. Now, run the start file you previously created.

GUESTn>**START**

Instead of running the start file, the single commands may be entered one by one. Below follows a summary of some necessary commands which basically form the START file. (For more detailed information about the commands, we refer to the handbooks at SEST)

OPERATOR name of operator, current directory
INVESTIGATOR,'name' name of observer
SYSTEM,B1950.0 define coordinate system
VSOURCE,vel1,[vel2],[+s:vsys],[+d:method] define velocity, velocity system, and type of doppler correction
CONNECT,rec:aos,[rec:aos] set the combination of receiver and spectrometer that will be used during the observations

MOLECULE,'name' name of molecule to observe
LINE,lrsfreq,[hrsfreq],[sideband] define the rest frequency
OBSMODE,(T|W|N|L|S|F) define observing mode
INTTIME,(SPE|REF|CAL),time define integration times
PROJECT,aaaa,bb project identification and type

If you need to start the whole system from scratch, e.g. after the computer has been rebooted, the STARTUP file should be scheduled before the START file. Before using STARTUP, ask the staff for assistance.

For on-line data reduction and as a quick-look facility, the data reduction program DRP is available and used on the HP graphics terminal in the control room. After logging on to the DRP terminal, you invoke the DRP programs with:

GUESTn>**DRP**

See Chapter 5 for further information about the DRP.

4.7 Tracking a source

The most convenient way to track a source is to have prepared a source list, called SOURCE.LIST and use the GOTO command. This command will look up the source name in the source list and read the coordinate system, and the name, coordinates and velocity of the source. To do this, enter:

GUESTn>**GOTO,'sourcename',[filename]**

If you have given your source list a file name different from SOURCE.LIST, that file name also needs to be included.

To track a source that is included in the pointing library use:

GUESTn>**GOTO,'sourcename',poilib**

The current AZ/EL position on the sky is displayed for the source and the user will be asked if he or she wants to track it or not. The following commands may be used to track a source instead of using GOTO:

ONPOS,long,lat source coordinates
REFPOS,long,lat,[A|R],[T|F] reference position (used for positionswitch, and possibly frequency switch)
TRACK,[ON|REF] track on position or ref. position

SOURCE,'name' source name
VSOURCE,vel1,[vel2],[+S:vsys],[+D:method] source velocity, velocity system and doppler correction method.

4.7.1 Tracking a planet

To track a planet, make sure that you are in EPOCH1950.0 (SYSTEM B1950). Then type:

GUESTn>**GOTO,planetname**

The current AZ/EL position on the sky is displayed for the planet. If the user wants to track the planet, the present epoch will be set, and the antenna will start to track.

Remember: *After each source change, check LO1 phase lock and the mixer current before starting an integration. If your sources have very different velocities, you may have to retune the receiver before an integration.*

4.8 Selection of receiver and spectrometer

To select the combination of receiver(s) and spectrometer(s) that will be used during the observations, the CONNECT command should be used. In the SEST commands the frequency rather than the wavelength is used to define the receiver. Thus the 3 mm receiver is called the 115 GHz receiver, the 1.3 mm receiver is called the 230 GHz receiver, and the 0.8 mm receiver is called the 345 GHz receiver. The syntax of the CONNECT command is the following:

GUESTn>**CONNECT,rec:aos,[rec,aos]**

where rec = (115A|115B|230|345|) specifies the receiver, and aos = (HR|LR) specifies the High Resolution and one of the Low Resolution spectrometers. The command keeps track of which of the low resolution spectrometers that will be connected to the specified receiver(s). Note that only two spectrometers can be used simultaneously. It is possible to use one receiver at a time, to use the two 3 mm receivers simultaneously, or to use the 3 mm receiver (Mixer B) simultaneously with the 1.3 mm receiver. The 0.8 mm receiver can not be used simultaneously with another receiver.
Examples: To connect the low and high resolution spectrometer to the 1.3 mm receiver:

GUESTn>**CONNECT,230:lr+hr**

To connect both low resolution spectrometers to the 3 mm receiver:

GUESTn>**CONNECT,115A:lr,115B:lr**

To do simultaneous observations with the 3 and 1.3 mm receivers using the low resolution spectrometers:

GUESTn>**CONNECT,230:lr,115B:lr**

To do simultaneous observations with the 3 and 1.3 mm receivers using the high resolution spectrometer:

GUESTn>**CONNECT,230:hr,115B:hr**

In this case the high resolution spectrometer is split into two parts.

4.9 Frequency and velocity settings

The observed frequency can be set by using the command

GUESTn>**GETLINE,moleculename**

The GETLINE program runs through the Lovas list of molecular restfrequencies until the requested molecular transition is found.

If the 3 and 1.3 mm receivers will be used simultaneously the command

GUESTn>**GETLINES,molecule1[,molecule2]**

can be used to select one transition within each of the tuning ranges of the two receivers.

The command LINE can also be used to set the observed frequency:

GUESTn>**LINE,freq1,[freq2]**

where freq1 and freq2 is the LRS and HRS center frequency if only one receiver is used, or they are the center frequencies for the spectrometers connected to the 3 and 1.3 mm receivers, respectively, if both receivers are used simultaneously. The combinations of receivers and spectrometers are selected with the CONNECT command.

The source velocity can be given with respect to the local standard of rest (LSR), as heliocentric (HEL), geocentric (GEO), or topocentric (TOP). The type of Doppler correction can be chosen as relativistic (REL), optical (OPT), or radio (RAD), see Section 3.1.5.

The source velocity is normally given in the source list file, and the velocity system and doppler correction method in the start file. It is possible to modify these settings with the command

GUESTn>**VSOURCE,vel1,[vel2],[+s:vsys],[+d:method]**

Example: To set the source velocity to 5 km s^{-1} for the LRS in single receiver mode using the heliocentric velocity system and with radio convention for the doppler shift type:

GUESTn>**VSOURCE,5,,+s:hel,+d:rad**

4.10 Observing modes

For spectral line observations there are basically three different observing modes described in Section 3.1.1:

- Position switching (total power)
- Beam switching
- Frequency switching

The mode to be chosen depends on requirements such as baseline quality or source characteristics like line width and extent.

The observing mode is selected with the command:

GUESTn>**OBSMODE,mode,[parameter]**

where mode is:

Total	= total power mode (position switch)
Wide	= wide beam switch (11.6' between the beams)
Narrow	= narrow beam switch (2.5')
Freq	= frequency switching

and parameter:

Throw = frequency throw in MHz
Dual = dual beam switch
Single = single beam switch

Examples: To select the beam swich mode with the wide separation between the beams type:

GUESTn>**OBSMODE,W,D**

To select frequency switch mode with a throw of 10 MHz type:

GUESTn>**OBSMODE,F,10**

4.11 Receiver Tuning

4.11.1 General remarks

Before starting an observation, the receiver must be tuned to the desired frequency. The tuning ranges are:

80 - 116 GHz for the 3 mm receiver
215 - 275 GHz for the 1.3 mm receiver
320 - 360 GHz for the 0.8 mm receiver

The procedure is done from the control room. Use the commands VSOURCE and LINE or GETLINE to set the LO1 frequency. The doppler corrected sky frequency will be calculated automatically. It is a good idea to track your source before tuning the receiver in order to obtain the correct sky frequency (see Section 4.7).

The command TUNE is then used to tune the 3 and 1.3 mm receivers. The 0.8 mm receiver is tuned from an Olivetti PC in the control room. A communications program between the HP and the PC sends sky and LO frequencies to the PC if the 0.8 mm receiver is selected.

The phaselock signal for the first LO can be seen on the spectrum analyzer in the electronics rack to your left. The spectrum analyzer is under computer control and can be connected to the various receivers and its display scaled with the command:

GUESTn>**SPAN,rec,scale**

where rec = (115|230|345|) specifies the receiver, and scale = (w|n) specifies the setting of the display (wide or narrow frequency scale).

4.11.2 Tuning the 3 mm receiver

The command TUNE is used to calculate and send servo settings to the receiver. It also allows a manual change of receiver settings (which is important for fine tuning).. There are two options: either use the automatic tuning or read parameters from a previously saved tune file.

GUESTn>**TUNE** to calculate the tuning parameters
GUESTn>**TUNE, filename** to use tuning parameters from a file

When TUNE is scheduled, frequencies and servo settings will be displayed on the screen. The tuning sequence continues with locking the MULTIPLIER. If it is locked successfully, the user will be asked if he or she wants to continue. By answering: Y, the tune process continues and now the GUNN display shown in Fig. 1a will appear on the screen. Blinking numbers in the 'tune' and 'backshort' fields indicate that the tuning of the Gunn oscillator has not yet finished. Wait until the setting is complete.

1. Check the control voltage and try to obtain a value between 3.7 and 3.9 V by changing the Gunn bias using key <f3>. The present value can be changed with the <+> and <-> keys on the numeric keypad or by typing in a three digit value (no <Return> is needed).

2. There should now be a strong signal on the MS610A spectrum analyzer in the rack to your left. Try to set it near the center of the display (at 400 MHz) by changing the Gunn tuning <f1> using the <+> and <-> keys. The upper sideband is used which makes the signal move to the left when the <+> key is used. Once you get the signal close to 400 MHz, lock it by first using the frequency lock key <f5> and then the phase lock key <f6>. If the message 'phase unlocked' appears on the screen and you hear the phase lock alarm, it means that the Gunn oscillator is not locked. You then have to open the lock with the <f5> and <f6> keys and repeat procedures 1 and 2.

3. When the signal is locked you may change the scale on the spectrum analyzer using the '<' key (the '>' key gives back the wider display). To obtain minimum phase lock sidebands try to adjust the loop gain using key <f4>.

4. When you are satisfied with the Gunn oscillator tuning, leave the Gunn display using the exit key <f8>.

5. When you are asked if you want to go on to the mixer menu, answer: Y, and the mixer display, shown in Fig. 1b, will appear. Wait until the setting is complete. The automatic tuning comes close to the correct mixer settings, but you will have to lower the LO attenuator setting using key <f1> to increase the mixer current. The value of the mixer current should be between 0.3 and 0.4 mA. The lowest value of the LO attenuator is 450. In frequency switch mode you can balance the mixer current at the two frequencies by moving the backshort for the mixer that is not used. When you are satisfied with the tuning of the mixer, the level of the AOS bandpass curve seen on the oscilloscope should be adjusted to its correct setting (about one division on the oscilloscope display), using the step attenuators in the rack to your left.

6. You can now determine the receiver temperature by typing the command RECTEMP on the other control terminal. The RECTEMP program is described in section 4.11.5. If you are not satisfied with the value of the receiver temperature, you can try to optimize it by adjusting the mixer current and/or mixer bias voltage (<f5> and <f6> for Mixer A or B).

Remember 1: *Do not try to optimize the receiver temperature using the mixer backshort. The setting of the backshort determines the image sideband rejection and is automatically set to maximum rejection.* The image rejection can be checked by inserting the test signal. Type 'T' in the mixer display to inject the signal, and 'I' to select the image band frequency. A signal should now appear on the oscilloscope showing the AOS bandpass curve. Minimize this signal by changing the setting of the mixer backshort.

Remember 2: *The setting of the two mixers affect each other because they share the local oscillator signal. Changing the mixer backshort or bias setting of one mixer will affect the current in the other mixer.* This can be used to increase the current in one of the mixers, if it is not enough to lower the LO attenuation to its minimum value. It can also be used to obtain the same current for the two frequencies in the frequency switch mode, which is very useful since fairly straight spectral baselines can be obtained this way.

When the tuning procedure is completed you can save the current parameters into a file using the command:

GUESTn>**RXSAVE, filename**

To list the file, use the command:

GUESTn>**RXLIST, filename,[lu]**

where lu=6 if you want to send the listing to the printer. If you want to find out which tune files that exists, use:

GUESTn>**RXCHECK**

Tune files older than 2–3 months are deleted.

4.11.3 Tuning the 1.3 mm receiver

Define the rest frequency using LINE or GETLINE from the HP. Lower sideband will be used for frequencies below 260 GHz and Upper sideband for frequencies above.

The TUNE command will schedule the program and set the servos to their default values for the specified sky frequency. (If a frequency conflict between the HP and the 230 GHz receiver controller occurs, the user will be notified. LINE or GETLINE should then be used again to set up the frequencies.)

The tune display shows all the servos and parameters for the 230 GHz receiver. A set of function key menus on the bottom line <f1>, <f2>, , , ,<f8> provides the user with full access to the different units. At startup the main menu is shown. From the main menu, one of six different sub menus can be selected using <f1> to <f6>. To exit the program, <f8> from the main menu should be used. Using <f8> from any sub menu takes you back to the main menu.

When a servo is selected, it can be set typing a two or three digit number or it can be fine adjusted using the <+> or <–> keys. On the bottom frame line to the right, three values (Low, Now and High will appear). These values represent the actual read position and the limits for the current servo selected. The program prevents you from exceeding the limits. A set value will blink as long as it differs from the corresponding read value with more than 2 units.

In the normal case, the quick menu, <f1> from the main menu, will be sufficient to use for the tuning.

Proceed in the following way:

1. Phaselock the Gunn oscillator. First check the Gunn control voltage. It should have a value between just below 9.0 V. Normally it does not need to be adjusted, but if necessary the servo can be accessed in the Gunn menu using key <f3> and changed using the <+> and <-> keys on the numeric keypad or by typing in a three digit value.

2. There should now be a strong signal on the MS610A spectrum analyzer in the rack to your left. Try to set it near the center of the display (at 400 MHz) by changing the Gunn tuning <f1> using the <+> and <-> keys. The upper sideband is used which makes the signal move to the left when the <-> key is used. Once you get the signal close to 400 MHz, lock it

by first using the frequency lock key <f2> and then the phase lock key <f3>. If the message 'unlocked' appears on the screen and you hear the phase lock alarm, it means that the Gunn oscillator is not locked. You then have to open the lock with the <f3> and <f2> keys and repeat procedures 1 and 2.

3. When the signal is locked you may change the scale on the spectrum analyzer using the '<' key (the '>' key gives back the wider display). To obtain minimum phase lock sidebands try to adjust the loop gain using key <f4>. It should be set between 12 and 22.

4. The SIS mixer should now be optimized. If the mixer should be in its protected status go to the mixer menu, use <f5> and answer 'Y' when the program asks you if you really want to unprotect the mixer. Set the mixer current to 18-20 μA by adjusting the LO attenuator, <f6> in the quick menu. Adjust the level of the AOS bandpass curve seen on the oscilloscope in the rack to your left to its correct setting (about one division on the oscilloscope display), using the step attenuators also in the rack to your left.

   Set the magnetic field current <f7> to minimize the IF level visible on the AOS oscilloscope. The best value can differ from day to day, but a current of about 80 units seems to be a good start. Do not exceed 110 units.

   Start RECTEMP on the the other control terminal to measure the receiver temperature. If it is very high (1000 K) check that IF attenuation for channel 1 is properly set to around 20 to 22. Look at the level on oscilloscope. If not, set it manually.

   To optimize the receiver temperature, the magnet current, the mixer backshort and the LO attenuation can be adjusted. The image rejection of the 230 GHz receiver is determined by the SSB diplexer. Its setting should not be changed. The mixer is tuned to DSB with the mixer backshorts, and the receiver temperature of the 230 GHz receiver can be optimized also by changing the mixer backshort settings. This is however normally not necessary.

   The image rejection can be checked by injecting a test signal using the mixer display. Use <f5> from the main menu to access the test signal menu. Choose the image frequency, and if you want to optimize the image rejection, minimize the signal in the AOS bandpass display on the oscilloscope by changing the setting of the SSB diplexer. This is however normally not necessary.

If you have to move several servos in order to achieve a good receiver temperature, it is advisable to save the settings into a file. These settings can then later be retrieved instantly without the need to go through the whole procedure once again. Use <f6> from the main menu to access the tunefile menu. Use the save to tunefile or read tunefile options.

To exit the display use <f8> to go back to the main menu and then <f8> once again to exit.

4.11.4 Tuning the 0.8 mm receiver

The 0.8 mm receiver has an SIS mixer and is tuned and optimized in a way similar to the 1.3 mm receiver.

The Olivetti PC runs a tuning program and displays a screen similar to the one on the HP for the 1.3 mm receiver. The servos can be accessed by moving the pointer with the mouse to the desired servo, and by clicking the mouse button. A keypad is then displayed on part of the screen and values can be entered by clicking on the number keys or the <+> and <-> keys.

Tune the receiver by clicking on the tune button and wait until all servos have reached their final values.

The Gunn bias voltage should be close to 9.0 V. In the same way as for tuning the other receivers, move the spike seen on the spectrum analyzer display in the rack to your left to the center, and frequency and phase lock the Gunn oscillator. The mixer should be optimized by adjusting the mixer current with the LO attenuation and by adjusting the mixer bias voltage and magnet current. Normally the backshorts and diplexers should not be moved.

Run RECTEMP to check the receiver temperature. The final servo settings can be saved on the PC by clicking on the SAVE button and giving a file name.

4.11.5 Measuring the receiver temperature

To measure the receiver temperature, the relation:

$$10^{0.1\,\mathrm{dBL}} = \frac{T_{\mathrm{rec}} + T_{\mathrm{hot}}}{T_{\mathrm{rec}} + T_{\mathrm{cold}}} \tag{4.1}$$

is used, where T_{hot} and T_{cold} are the physical temperatures of the loads which are read by the computer, and dbL is the difference between $(T_{\mathrm{rec}} + T_{\mathrm{hot}})$ and $(T_{\mathrm{rec}} + T_{\mathrm{cold}})$ in decibels. The dBL value is obtained by running a calibration on the AOS while switching between the two loads. From these values T_{rec} is calculated. The standard program to do this is called RECTEMP. Keep the MIXER display on the screen and schedule RECTEMP from the other terminal. The program selects wide beam switch and moves in the loads. You have the option to make several measurements. When you are finished, exit both programs. RECTEMP will restore the previous OBSMODE and move out the loads.

4.11.6 Relocking the Gunn oscillator

The AOS program will check the phase locking every 5 seconds during integration and exit when it detects a failure. If this happens you need to lock it again. It is not necessary to go through the whole tuning procedure again using TUNE, but the following commands can be used to reenter the tune program without changing any servo settings. For thc 3 mm receiver type:

GUESTn>**GUNN**

For the 1.3 mm receiver type:

GUESTn>**RX230**

To lock the Gunn oscillator of the 0.8 mm receiver, use the Olivetti PC.

4.11.7 Adjusting the Mixer current

If the mixer current needs to be adjusted type the following for the 3 mm receiver:

GUESTn>**MIXER**

and for the 1.3 mm receiver:

GUESTn>**RX230**

When the mixer current is adjusted, exit the program.

To adjust the mixer current of the 0.8 mm receiver, use the Olivetti PC.

Remember: *The mixer current is checked every 5 minutes. If it is too low or too high, an alarm is activated.*

4.12 Pointing checks

The SEST pointing sources are listed in Appendix B. They consist of both spectral line and continuum sources. The spectral line sources are either SiO masers or CO sources (circumstellar envelopes). In both cases a five point map around the source position is made. If not otherwise specified, the spacing between the map points is half the beamwidth at the observed frequency. Offsets in azimuth and elevation are calculated from a two dimensional Gaussian fit and entered as pointing offsets.

A pointing is done in the following way:

1. Track the source selected from the pointing library using the command:

GUESTn>**GOTO,'sourcename',poilib**

2. Tune the receiver to a line or to a continuum frequency, using LINE or GETLINE and TUNE.

3a. If you are tracking a spectral line source start the pointing with the command:

GUESTn>**POINTING,LINE,times**

3b. If you choose a continuum source from the pointing library or a planet, track the source with the GOTO command and then enter:

GUESTn>**POINTING,CONT,times**

4. If your pointing source is near the source ($<10°$) you want to observe, you can keep the pointing offsets. For larger distances the pointing may change between the two positions and the offsets should be removed by typing:

GUESTn>**POINT,0,0**

If your pointing offsets are larger than 10", you should consult the SEST staff.

5. Resume normal observation. The pointing program will restore the initial setting you had before the pointing started.

The spectra obtained during the pointing are saved in a subdirectory in your GUEST account.

Normally the pointing program selects the observing mode, integration time, and spacing between the points in the five point map. The observer can change this by adding a few options to the POINTING command. They are the following:
+S:space to set the spacing.
+I:time to set the integration time.
+M:mode to set the observing mode.
+F:filename to obtain pointing parameters of sources not in the pointing library from a previously prepared file.
+A or +B to do a pointing with only the 3 mm or the 1.3 mm receiver if both

of them are used simultaneously.
Examples: To perform one 5 point map with default spacing, around the position of the Orion SiO maser:

GUESTn>**GOTO,'Orion SiO', poilib**
GUESTn>**POINTING,LINE,1**

To perform three five point maps around Jupiter with a a spacing of 30":

GUESTn>**GOTO,Jupiter**
GUESTn>**POINTING,CONT,3,+S:30**

To help in the selection of an appropriate pointing source it is possible to plot the visibility of the sources in the SEST pointing library by using:

GUESTn>**PREDICT,POILIB**

To list the positions of visible sources in the SEST pointing library, use:

GUESTn>**AZEL,,POILIB,,***

4.13 Focus checks

The correction for the homology of the telescope is done by a control program and the corrections are not visible to the observer. On top of this there is a small focus change that seems to be dependent on the outside temperature. Especially there is a change between day and night that can be as large as 0.5 mm. There is a program that makes a first order correction for this effect when the 3 mm or 1.3 mm receiver is used, and normally it is not necessary to check the focus during observations with these receivers. However, when the 0.8 mm receiver is used it is necessary to check the focus, especially after sunrise and sunset. If no suitable source for focusing is available at 0.8 mm, it is possible to do a focus check at a 3 mm source (e.g. a SiO maser) and use the results with the 0.8 mm receiver. To focus on a source it is first necessay to track it with the GOTO command and to perform a pointing on the source. Usually a planet or a source from the pointing library is used. If you are using a spectral line source, do the focus check with the command:

GUESTn>**SUBPOINTING,LINE,times**

If you have chosen a continuum source from the pointing library or a planet enter:

GUESTn>**SUBPOINTING,CONT,times**

The program observes the source at zero focus offset and then at default offsets depending on which receiver that is used, and determines and enters the new focus offset. This can be done several times and the average of the offsets are entered. The integration time is the one defined in the pointing library. It is also possible to add some options to the SUBPOINTING command to reset integation times, and to change offset values and observing mode.
The focus offset can be set manually with the command:

GUESTn>**SUBPOS, offset in mm**

Note that all focus offsets entered with the SUBPOS command are offsets on top of the correction for the homology of the telescope.

4.14 Integrating

4.14.1 Integrating in one position

The command INTEGRATE allows you to perform an integration:

INTEGRATE,ncycle,nspec[,option]

Parameters:

ncycle: number of cycles to integrate. A cycle means typically a calibration, followed by a number of spectra, and saving the average (if specified)
nspec: number of spectra to take
option: (+C|+NOR|+RMS|+S:which)
which: = C for calibration
= S for spectra
= A for average
= R for reference

This command will move the telescope to the currently commanded position and take nspec spectra, optionally making a calibration if the +C option had been specified. Note that for position switching and frequency switching (for strong sources), a reference position should be defined. For total power

mode a reference spectrum will always be taken before each spectrum, unless +NOR is given as an option. Use OBSMODE to select between single and dual beam switch. Use +RMS to calculate the integration time after each calibration. The option +S determines which spectra are going to be saved on the disc. By default only calibrated spectra are saved.
Examples:

GUESTn> **INTEGRATE,1,1,+C**

A calibration is performed and one spectrum is taken. The spectrum is saved.

GUESTn> **INTEGRATE,0,0,+C**

Only a calibration is performed. Nothing is saved.

GUESTn> **INTEGRATE,2,5,+C,+S:SA**

Assuming wide dual beam switch, five spectra pairs are taken after an initial calibration. The spectra and their average are saved. This sequence is repeated twice. As a result, 20 spectra and 2 averages will be saved.

4.14.2 Mapping

The mapping procedure allows you to make rectangular maps, strip maps, five point maps, and to map a set of grid positions supplied from a file. The maps can be tilted by defining a tilt angle (increasing from north toward east, Fig 4.1). The maps are defined in grid coordinates (x and y) with respect to the current ON position. A reference position can be given either in relative or absolute coordinates using the REFPOS command. The observing mode is defined by the command OBSMODE.

Note that for mapping of galaxies the normal convention is to define the position angle of the major axis as increasing from north towards east. Thus in order to map the major axis of a galaxy with the position angle defined as above, the tilt angle should be set to 90° + position angle.

The map parameters need to be defined before the map is started. This can be accomplished in two ways:

1. Use the MAPSETUP command to create a command file. Type:

GUESTn>**MAPSETUP**

and select option 1. Fill in the displayed form and exit by pressing <Enter>. To actually enter the parameters into the computer, you need to schedule the file, simply by typing its name in the same way as executing the start file. (A file with grid positions to be mapped can be created by using option 2 in MAPSETUP.)

2. Separate MAP commands could be issued according to the following:

MAP,GRID,XSIZE,x1,x2,ix
MAP,GRID,YSIZE,y1,y2,iy
MAP,GRID,STEP,dx,[dy]
MAP,GRID,SYSTEM,sys
MAP,GRID,TILT,angle
MAP,NCAL,n
MAP,NSPE,n
MAP,NREF,n
MAP,POS,[nx,ny]

Start the mapping with:
  MAP GO [,options]

Parameters:

options	+S:which	to indicate which spectra to save
	which	= C for calibration
		= R for reference spectra
		= S for spectra
		= A for average
	+NOR	take no reference spectra
	+RMS	to calculate integration times after each calibration
	+FOUR	make a four point map around the center position
	+FIVE	make a five point map including the center position
	+UDMS	map the positions given in file with grid positions
	+PART	to start from the current position in the grid

Examples (see Fig 4.1):

Make a 5x5 point map in descriptive coordinates with 25" between each map point. Take 2 spectra on each position and save both spectra and average. Make a calibration every 8th integration (every 4th map point).

GUESTn> **MAP,GRID,XSIZE,-2,2,1**
GUESTn> **MAP,GRID,YSIZE,-2,2,1**
GUESTn> **MAP,GRID,STEP,25",25"**
GUESTn> **MAP,GRID,SYSTEM,DES**

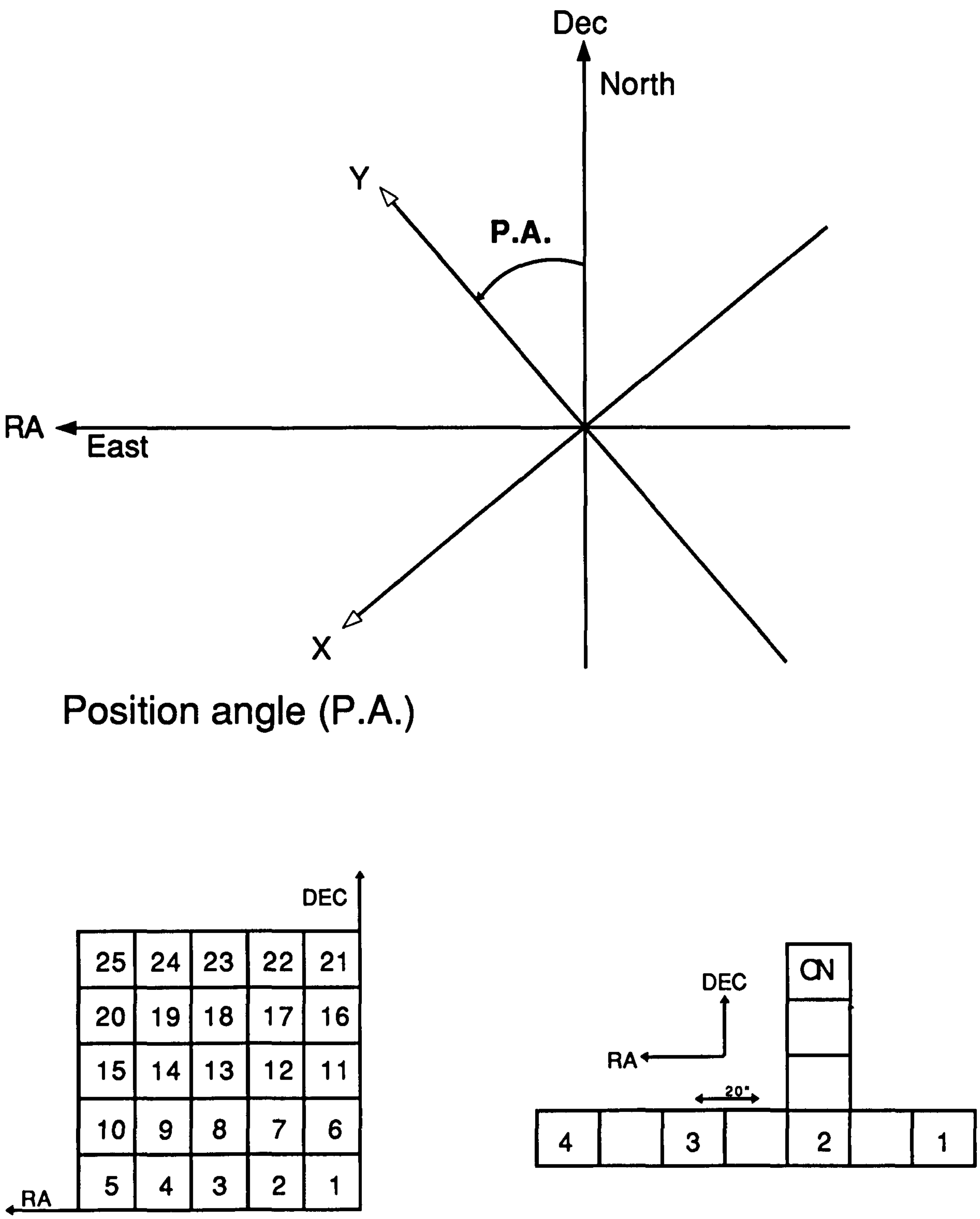

Figure 4.1: Map definitions

GUESTn> **MAP,NCAL,8**
GUESTn> **MAP,NSPE,2**
GUESTn> **MAP,GO,+S:SA**

Make a strip map in RA south of the central position of the source. Define a spacing of 20", but take a spectrum only on every second grid position, i.e. every 40". Calibrate on every position.

GUESTn> **MAP,GRID,XSIZE,-2,4,2**
GUESTn> **MAP,GRID,YSIZE,-3,-3,1**
GUESTn> **MAP,GRID,STEP,20",20"**
GUESTn> **MAP,GRID,SYSTEM,DES**
GUESTn> **MAP,NCAL,1**
GUESTn> **MAP,NSPE,1**
GUESTn> **MAP,GO**

4.14.3 How to stop an integration

In order to stop an on-going integration, you can either make an immediate abort without saving data, or you can make a smooth stop waiting until the current integration has finished, and save the data on disc. In dual beam switch mode the second spectrum is also collected before stopping.

During an integration you need to press the <Break> key to receive the CM> prompt. Use:

CM>**STOP,NOW**

to immediately abort the on-going integration (i.e. the AOS program) without saving data.

Use:

CM>**STOP,INTEGRATE**

to stop INTEGRATE but wait until current integration has finished, and then save the data, or

CM>**STOP,MAP**

to smoothly stop the map after the present integration has finished. Save the data.

Use:

CM>STOP,POINTING

to abort the POINTING program. The current integration will finish and maybe also the next if you use dual beam switch mode. Then the program will restore the initial settings, by-passing the Gaussian fit, and exit.

4.15 Bolometer observations

4.15.1 ON-OFF measurements

ON-OFF measurements with the bolometer normally consist of making a skydip to find the atmospheric opacity, going to a pointing source to do a pointing and a focus check, and finally going to the source to do ON-OFF measurements. It is also necessary to occasionally observe a calibrator source. At SEST the planet URANUS serves as a primary calibrator and the other planets as well as a dust source in Orion serve as secondary calibrators.

The atmospheric opacity is determined by doing a skydip, i.e. the telescope is moved to 6 different elevations, integrates 10 seconds on each position and calculates the zenith opacity. A skydip is done with the command CDIP:

GUESTn> **CDIP [,azimuth]**

The current azimuth will be used if not specified. The result of the opacity calculation is displayed on the screen and entered into the computer. A continuum scan in ASCII format is saved as a result of each skydip.

A pointing source can be selected from the pointing library of bolometer sources. The file is called BOLOMETER.LIST. A bright source near the source to be observed should be selected. Track the pointing source with the command:

GUESTn>**GOTO,'sourcename',bolometer.list**

Then use the following command to do the pointing:

GUESTn>**CPOINTING [,times] [,spacing] [,inttime]**

A pointing consisting of a 5-point map (-AZ,ON,+AZ,-EL,+EL) is made and a two dimensional Gaussian is fitted to the data. If runstring parameters are not supplied, the default values are: 1 map, 12 arcseconds spacing and

10 seconds of integration on each position. The resulting offset is entered automatically on the screen.

A focus check should then be done on the same source with the command:

GUESTn>**CFOCUS,times,offset**

This routine will integrate 10 seconds on the source for each of the subreflector positions ON,-OFF,+OFF (given in mm) and gives the optimum axial offset for the subreflector focus. This offset is entered automatically for the following observations. Normally an offset of 0.8 mm should be used.

The source to be observed can be tracked with the GOTO cammand and the ON-OFF measurements are done with the command:

GUESTn>**CONOFF,loops,pairs**

Pairs specifies the number of ON-OFFs (an even number of pairs must be specified), while loops is the number of times to run the procedure. The integration is fixed to 10 seconds on each position. A continuum scan in ASCII format is saved after each run.

It is also possible to scan across a source in a given direction and velocity:

GUESTn>**CSCAN,length,velocity,direction**

A scan can be made in horizontal or equatorial coordinates. Length and velocity parameters specifies the length in arcsec and the velocity in arcsec/second. Do not forget to supply units. The direction can be either +AZ, -AZ, +EL, -EL, +L, -L, +B, -B. A scan will be saved in DRP format.

The continuum scans (i.e. the results from skydip and ON-OFF measurements) are stored in ASCII format on the disk. They contain relevant observing parameters in the header and the results of the measurements. They can be listed with:

GUESTn>**CLIST,(scan|ALL)** [,lu]

The listing is sent to the screen (default) or to the printer (lu=6). Use ALL to list all scans. Ex: List all continuum scans on the printer; CLIST,ALL,6

To do a quick data reduction the following command can be used:

GUESTn>**CREDIT,firstscan,lastscan,[+P|+F:file|+T:tau|+C:fact]**

A total mean value of all data in the scans of the specified scanrange is given, corrected for the atmospheric opacity given in the header. The output can be directed to the screen, to the printer (+P) or a file (+F). If you want to use a different optical depth than that given in the header use +T. With +C the result is not corrected for the optical depth, instead it is multiplied with the specified multiplication factor.

4.15.2 Aborting an integration

Some of the bolometer commands can be aborted and the integration stopped by pressing the <break> key and enter:
CM> STOP,CDIP
CM> STOP,CPOINTING
CM> STOP,CFOCUS
CM> STOP,CONOFF

4.15.3 Bolometer mapping

Mapping is done in a dual-beam scanning mode, and the data is later restored to an equivalent single-beam observation. The mapping is done in horizontal coordinates (azimuth-elevation) and the map is transformed to equatorial coordinates during the subsequent data reduction. The command to perform a map is the following:

GUESTn>**CMAP,xlength,ylength,yinterval,xvel**

where xlength and ylength are the sizes of the map in azimuth and elevation, yinterval the angular step in elevation between the azimuth scans, and xvel the azimuth scan velocity in angle/sec.

The result of the map is stored as an ASCII file in the HP. There is a data reduction package based on the NOD2 system (developed by G. Haslam) on a PC486 in the SEST control room. The ASCII file can be transferred to the PC using FTP. The staff will give an introduction to the data reduction package for the observer to have a quick-look facility and to plan the further observations. The observer is however responsible for the final data reduction.

Before starting a map, a skydip, pointing, and focus should be done in the same way as for ON-OFF measurements.

A more detailed handbook for bolometer mapping is available in the SEST control room.

4.15.4 More bolometer commands

STARTUP,BOL

Must be used after a computer bootup to activate the control programs.
GAIN,n where n=1,9
To set the gain of the bolometer amplifier. The dBl value on the control display will show the gain setting for control.
PADDLE,(in|out)
To control the eccosorb load. It is used in the CDIP program. 'paddle in' is indicated by a negative dBl value on the screen, while a positive dBl value, indicates 'paddle out'.

4.16 End of an observing session

At the end of your session park the telescope before the next project starts, especially during daytime. Use:

GUESTn>**PARK**

and check that the telescope moves to a low south position. When the prompt appears again on the screen, put the telescope drive key (located under the alarm display in the left rack) to LOCAL.

To reset parameters and log off from your session, use:

GUESTn>**ENDOBSERVE**

and also log off from the other control terminal, use:

GUESTn>**EX**

On the DRP terminal you need to do:

DRP>**EX,L**

to terminate the DRP program and log off.

4.16.1 Data format

Each scan, i.e. the data obtained during an integration, may be written to the disc identified by a unique filename. These so called DRP scans have the following file name:

=ssssppppnnnn.typ

where

=	is the DRP scan file identifier
ssss	is the first 4 of the source name (spaces removed)
pppp	is the project identifier
nnnn	is the scan number (ranging between 1000 and 9999)
typ	is the file type extension (for example: CAL, SPE, AVE)

Continuum data taken with the Bolometer are saved in ASCII format and are called Continuum scans. They follow the pattern:

+ssssppppnnnn.CON

where

+	is the continuum scan file identifier
ssss	is the first 4 characters of the source name (spaces removed)
pppp	is the project identifier
nnnn	is the scan number (ranging between 1000 and 9999)

4.17 Data backup

It is the observers' responsibility to make a daily backup of their data to avoid data loss in case of a disc crash.

Each GUEST account has its own 1200-feet tape for daily temporary backups. This tape is found in the tape cabinet in the computer room. Mount your tape on the tape drive and type from your account:

GUESTn>**BACKUP**

This routine will initialize the tape and copy all the scans found.

When your project is finished, the staff will make a full archive backup in SEST format which will be kept for a long time (several years), and also assist you in making an export tape in FITS format. Continuum scans are saved in ASCII format.

The Kennedy tape drive (LU8) can read/write with the densities 800, 1600 and 6250 bpi. Inform the staff which size of the tape and which density you want for your export tape.

4.18 Troubleshooting

4.18.1 Telescope runaway

Loss of telescope control during daytime is particularly dangerous since it might position the telescope too close to the sun. One of the following three measures should stop the telescope:

a) Type TRACK NO on the control terminal.
b) Turn the key on the telescope drive into LOCAL.
c) If the antenna still does not stop, push the red emergency button.
d) Call the staff.

Note that the telescope has to be moved manually if it is within the sun limit. Always call the astronomer on duty for assistance.

The HP software will prevent the telescope to track a position within 50° from the sun. If this fails for any reason, the microprocessor controlling the telescope will quickly move away the telescope if it is tracking within 35° from the sun. Finally, the hardware protection, an infrared detector on the subreflector, will activate the sun alarm if it is approximately 20°–25° from the sun. In slew mode, the microprocessor inhibits the telescope to come closer than 30°.

4.18.2 Audible alarm

It could come from two different sources: The sun alarm siren or the alarm signaling unit.

Sun alarm

This a very loud and painful alarm that you notice immediatley. If you are alone in the control building: CALL THE STAFF IMMEDIATELY !

Alarm signaling unit

It is located in the left rack below the UTC and LST clocks. There are two columns of LEDs. The left one indicates hardware alarms, while the right one indicates software alarms.

Hardware alarm

Most often a phase lock failure. If it is, lock the Gunn oscillator. If any other type of alarm: Sun, Encoder, Emergency stop, Power or Operational: CALL THE STAFF IMMEDIATELY !

Software alarm

Take a look at the alarm text display above the signaling unit, and follow the recommended action. If the alarm is due to a high temperature or pressure in the receiver cryo boxes, CALL THE STAFF IMMEDIATELY ! Possibly the alarm message is displayed on the control terminal instead of the alarm display or on both. Deactivate any software alarm using the command: GUESTn>**ALARM,RESET**

4.18.3 Computer failure

An indication of a computer failure, is when the display program stops to update or that pressing the <Break> key doesn't result in a CM prompt. In this case, call the staff immediately, and keep an eye on the telescope, especially during day-time.

4.18.4 No update on the control display, LU 40

Below the PC monitor, there are instructions on how to bootup the display terminal. Follow the instructions or call the staff for assistance.

4.18.5 Computer link error message

When the communication between the A900 and A600 computer fails for any reason, there can be messages on the system terminal, the control terminal or on the AOS terminal. Try first to reboot the A600. Follow boot instructions on the AOS terminal. If it doesn't help, call the staff for assistance.

4.18.6 Multiprogrammer error, LU 31

A Multiprogrammer error is most probably the reason for strange behaviour of the receiver tune programs. You can see the program status with:

GUESTn>**WH**

If the message "Down LUs: 31" appears, issue a:

GUESTn>**UP,31**

In any case, reset the multiprogrammer with:

GUESTn>**CN,31,0**

If you still have problems, do not hesitate to call the staff for assistance.

4.19 Some useful utilities

In addition to the previously mentioned, most frequently used SEST commands, there are a number of different general purpose programs, that might be of interest for the observer. Use the DOC command to get a more detailed explanation.

ALERT Activates a software alarm during 2 seconds.
AZEL Displays current AZ/EL coordinates for sources in a file.
CLS Clears the screen.
CREDIT To reduce continuum data.
FLUX Calculates the flux from a planet in Jansky.
GETOFFLINE Gives line frequencies from the LOVAS table (no update online!).
GRIDCHECK Calculates positions for a given grid with given spacing and tilt.
HPBW Calculates the antenna half power beam width.
HP45 Simulates an HP45 pocket calculator.
MUSIC plays a short piece of music on the HP.
PHTEMP Displays physical temperatures for the two receivers, for the loads, in the antenna cabin etc.
PLASPA To calculate the spacing used for planet pointing.
PLAZEL Displays current AZ/EL coordinates for all planets.
PRINTS Sends a screen dump of the alphanumeric display to the printer.
SCOUNT Counts the number of scans on a directory.
SKYDIP Makes a skydip to obtain the atmospheric optical depth.
TAU Calculates the current optical depth.
TELESCOPE Views telescope and subreflector position and status.
TRANSFORM Converts between RA/DEC, AZ/EL, and Galactic coordinates.
VISI Calculates rise and set times for sources.
WHERE Displays current AZ/EL coordinates for one source at any LST.
WPAGE Displays weather info from ESO and SEST weather station.
WSPLOT Plots the last hour wind speed on a graphical screen.

Chapter 5

The Data Reduction Package, DRP

5.1 Introduction

The Data Reduction Package, DRP, was developed at SEST and consists of a number of small programs to be used for online data reduction. DRP follows the same philosophy as the telescope control software and is used in parallel with the ongoing observations.

As soon as a spectrum is stored on the disk it is accessable with DRP. Hardcopies of spectra can be made with the the plotter or the line printer, and there is a Thinkjet that produces hardcopies of the screen. When DRP is started a log file called DRP.LOG is created. The results of rms calculations, integrated intensities, and gaussian fits are stored in this file.

DRP accesses individual scans in individual files. This has the advantage of being able to use HP operating system commands to find, copy, delete, and rename scans.

5.2 How to start and stop DRP

A graphics terminal has to be used. The two graphics terminals available are: LU40 in the visitor's room and LU45 in the control room. Logon using your guest account and invoke the DRP programs typing:

GuestN> **DRP**

From now on, the prompt will be: 'GuestN–DRP>' although you still have access to all HP operating commands and the SEST commands.

To exit from DRP, type:

GuestN-DRP> **XDRP**

or logoff your session, using

GuestN-DRP> **EX,L**

5.3 Online help

DRP online help is obtained through the command:

GuestN-DRP> **DOC,cmd**

This will display information for command "cmd", in the same way as for the SEST commands.

5.4 Scans

Scans are stored as individual files where the name is chosen according to the following pattern:
=SSSSPPPPNNNN.TYP, where

=	unique scan identifier
SSSS	first four characters in source name
PPPP	project number supplied in the start file
NNNN	scan number (1000,...,9999)
TYP	extension indicating type of spectrum

Possible extensions are: SIG, REF, SPE, CAL and AVE.

During observations new scans are created by the AOS program. This program will never write over old data, i.e. in a situation where the combination of scan number, source and project would lead to an already existing scan, the AOS program will produce an error message.

On the other hand DRP allows you to write over existing scans with the PUT command. It is therefore advisable to never force PUT to produce any extensions of the ones named above, as this may overwrite original data.

It is easy to use the operating system's file masking capability to find scans that match certain attributes. (Type ?,mask to get help on file masks). A few examples:

=@.@	will fit all scans
=- - - - 4711 - - - -.@	will fit all scans taken for project 4711
=@.AVE	will fit all average scans

Example: to obtain a list of all scans with the extension AVE, type:

GuestN-DRP> **DL,=@.AVE**

5.5 How DRP works

The various commands in DRP communicate with each other through the three programs CWORK, CHOLD and CTEMP. Spectra are stored temporarily in one of three areas (CWORK, CHOLD and CTEMP), depending on the command.

CWORK normally holds the scan on which the user wants to perform an action. As a rule a command takes the scan from CWORK, modifies it and returns it to CWORK. If the user wants to act on the average area or the temporary area (see below) these have to be copied to CWORK first.

CHOLD is used for adding scans. The only commands that exist to act on CHOLD are ZERO, ACCUM and AVERAGE (see DRP command description for details).

CTEMP may hold a temporary scan, e.g. the results of a baseline or gauss fit. You may copy/subtract it to/from the work area.

5.6 DRP command summary

This is only a short description of the DRP commands. A full description is given in the DRP Handbook available in the SEST control room.

ACCUM Adds scan held by CWORK to the scan in CHOLD.

ADD first last [**step**] Adds a range of scans.

AREA x1 x2 ... x6 [**unit**] Calculates integrated intensities.

AVERAGE Averages and copies the scan held by CHOLD to CWORK.

BAD [**x1 x2**] [**unit**] [**option**] Marks channels as bad. The intensities in the selected channels are either set to zero or the average of the surrounding channels.

BASELINE [**x1**] [**x2**] [**x3**] [**x4**] [**unit**] [**order**] Fits a polynomial to a specified region of the spectrum.

BIAS Adds a constant to all channels of the scan held by CWORK.

BOXCAR [**n**] Performs a boxcar smoothing on the scan held by CWORK.

CENTRE longitude latitude Changes the centre position and recalculates

the offsets for scans in a map.
CLIP max [min] Intensities exceeding the limit values are set to the limit values.
CONVOLVE Convolves the spectra held by CWORK and CTEMP.
CORRELATE Calculates the correlation spectrum of CWORK and CTEMP.
DATA [x1] [x2] [unit] Displays the values of the specified channels on the screen.
DROP [x1] [x2] [unit] Drops any channels outside the specified range.
FFT [mode] Performs a fourier transform of the spectrum held by CWORK.
FOLD [throw] Folds frequency switched spectra.
GAUSS [amp centre width] [x1] [x2] [unit] Fits a Gaussian to the scan held by CWORK.
GET scan [typ] [source] [project] Reads a scan from disc into CWORK.
HANNING Performs Hanning smoothing on the scan held by CWORK.
HEADER [form] [lu] Displays header information of the scan held by CWORK.
INQUIRE Invokes the graphic cursor to read the intensity, velocity etc. at the cursor position.
LOG mask [lu] Writes scan information to output lu.
MAPPLOT firstscan, lastscan, step Plots several spectra on the screen or the plotter.
MAPSHOW which col what [option] Makes contour maps.
MAPVIEW xmin ymin xmax ymax Confines the plotting region on a graphic device.
MOMENT [x1] [x2] [unit] Calculates mean, integral, centroid and rms values for a given region.
PUT [extension] Saves a scan held in CWORK onto disc.
REDRES [n] Reduces the spectral resolution of the scan held by CWORK.
REVERSE Reverses spectrum held in CWORK in velocity.
REWIND Rewinds the logfile DRP.LOG.
SCALE factor Multiplies all channels of the scan held by CWORK with a constant.
SHIFT amount [unit] Shifts the spectrum held by CWORK by a given number of channels.
SHOW [x1] [x2] [unit] [y1] [y2] [options] Displays the spectrum held by CWORK on a graphic device.
SHOWFIT [option] Displays fit results.
SUBTRACT Subtracts the scan held by CTEMP from CWORK.
TCOPY Copies the scan held by CWORK to CTEMP.
TEMP Copies the scan held by CTEMP to CWORK.
VHEL Changes the velocity scale from LSR to HEL.
VIEWPORT xmin xmax ymin ymax Confines the region of the plotting

area.
VLSR Changes the velocity scale from HEL to LSR.
X command first last [step] Repeats a command a number of times for a range of scans.
ZERO Clears CHOLD.

5.7 Examples

5.7.1 How to display a spectrum

A spectrum with scan number 1000 is read into CWORK and displayed on the screen with the following two commands:

GuestN-DRP> **GET,1000;SHOW**

Several commands can be written on the same line provided that they are separated by a semicolon.

5.7.2 How to average spectra

To average e.g. three spectra with scannumbers 1000, 1002, 1004, type:

GuestN-DRP> **ZERO;ADD,1000,1004,2**

The spectra can also be averaged with the commands:

GuestN-DRP> **ZERO;GET,1000;ACCUM;GET,1002;ACCUM; GET,1004;ACCUM;AVERAGE**

5.7.3 Baseline fitting

To fit a 2:nd order baseline between the velocity intervals 10 to 50 and 75 to 100 kms^{-1} type:

GuestN-DRP> **BASELINE,10,50,75,100,VEL,2**

The result of the fit can be plotted on top of the spectrum with the command:

GuestN-DRP> **SHOWFIT**

To subtract the fitted polynomial type:

GuestN-DRP> **SUBTRACT**

5.7.4 Calculation of integrated intensities and rms values

Integrated intensities can be calculated with the AREA and MOMENT commands. To find the integrated intensity between 10 and 50 kms^{-1} type:

GuestN-DRP> **AREA,10,50,VEL**

or

GuestN-DRP> **MOMENT,10,50,VEL**

The result is displayed on the screen and written into the DRP.LOG file. The moment command also calculates centroid velocities, mean intensities, and rms values of the specified region.

5.7.5 Smoothing

Smoothing of spectra can be done by either of the three commands HANNING, REDRES, or BOXCAR.

5.7.6 Gaussian fits

The gauss fit program needs a first guess of peak intensity, center velocity, and line width. The region of the fit must also be supplied. To fit a gaussian to a line where the estimated peak intensity is 1.5 K, the center velocity is 2 kms^{-1}, and the line width is 1.3 kms^{-1} within the region -2 to 5 kms^{-1} type:

GuestN-DRP> **GAUSS,1.5,2,1.3,-2,5,VEL**

The result of the fit is diplayed on the screen and written into the DRP.LOG file. The result can be plotted on top of the spectrum with the command:

GuestN-DRP> **SHOWFIT**

5.8 Troubleshooting

5.8.1 How to stop an infinite LOOP

The program LOOP is started by e.g. the ADD command. If you make a mistake in specifying scan numbers you may end up with an infinite loop. To abort the loop program do the following sequence:
1. Press <Break> to receive the CM promt
2. Enter: CM> **BR,LOOP**

5.8.2 Plotter problem

Before you plot a spectrum, you have to load a paper into the plotter. If you forget to do this, an error message will appear on the screen. Proceed in the following way:
1. Load a paper into the plotter.
2. Press <Break> to receive the CM> prompt and type
CM> **UP,7**

Appendix A

A.1 SEST commands

The SEST commands are summarized below. A more detailed description is given in the SEST Handbook which is available in the SEST control room.

AIRTEMP	sets the ambient air temperature
ALARM	enables/disables software alarms
ALERT	gives a signal to aler the observer
AOS	controls the acousto optical spectrometers
AZEL	displays Az/El coordinates for a source at any LST
BACKUP	copies scans from disc to tape
BEAMSWITCH	display/control the quasi optical units
CDIP	makes a skydip using the bolometer
CFOCUS	optimizes the telescope focus using the bolometer
CHOPPER	controls the chopper wheel
CINFO	logs short continuum scan information
CLIST	lists continuum scan
CLOFF	clears all offsets
CONNECT	select receiver and spectrometer
CLS	clears the screen
CONOFF	makes ON-OFF integrations with the bolometer
CONSTRUCT	creates a start file or a source list
CPOINTING	pointing routine when using the bolometer
CREDIT	continuum data reduction routine
CSCAN	make a scan across a source using the bolometer
DOC	online explanation of SEST commands
ENDOBSERVE	resets user parameters and logoff
GAIN	sets the gain of the bolometer amplifier
GETLINE	sets the rest frequency of a given transition online
GETLINES	sets the rest frequency of given transitions online
GETOFFLINE	sets the rest frequency of a given transition offline
GOTO	finds and tracks a source from any source list

GUNN	displays/controls Gunn servos and settings
HPBW	calculates the antenna half power beam width
HUMIDITY	sets the relative air humidity
INTEGRATE	makes integrations with the spectrometer
INTTIME	defines integration times
INVESTIGATOR	sets the name of the investigator
LEVEL	sets the mixer current level
LINE	sets the line rest frequency
MAP	standard routine to setup and to make maps
MAPSETUP	creates a command file to define map parameters
MIXER	displays/controls mixer servos and currents
MOLECULE	sets the name of the molecule to observe
MULTIPLIER	displays/controls multiplier settings
MUSIC	plays a melody
OBSMODE	selects the observing mode
OFFSET	specifies offset in descriptive or horizontal system
ONPOS	specifies the coordinates of the ON position
PADDLE	controls the eccosorb load used with the bolometer
PARK	parks the telescope in a south position
PHTEMP	displays/logs various temperatures
PLAZEL	displays Az/El coordinates for the planets/moon
POINT	specifies the pointing correction
POINTING	standard pointing procedure
PREDICT	plots visibility for sources in a source list
PRESSURE	sets the ambient air pressure
PROJECT	defines the current project
QUASI	controls the quasi optical units
RECLOOP	calculates the receiver temperature continuously
RECTEMP	calculates the receiver temperature
REFPOS	specifies the coordinates of the reference position
RX230	displays and enables tuning of the 230 GHz receiver
RXCHECK	checks tune files on the tune directory
RXLIST	lists tune parameters
RXSAVE	saves tune parameters
SCANCONT	makes the telescope scan across a region with a given velocity
SCANNUMBER	defines next scannumber
SCOUNT	counts the number of scans in a directory
SHUTDOWN	sets the specufied receiver in a standby mode
SKYDIP	makes a skydip to calculate the atmospheric optical depth
SOURCE	specifies the name of the observed source
SPAN	sets the spectrum analyzer to the PLL for the selected receiver
STARTUP	starts up the observing control programs
STOP	stops ongoing integration

SUBPOINTING	optimizes the telescope focus using the spectrometer
SUBPOS	offsets the subreflector
SYSTEM	specifies coordinate system
TAU	calculates current atmospheric optical depth
TELESCOPE	views telescope and subreflector position and status
TESTSIGNAL	enables the testsignal to check the frequency of a receiver
TRACK	tracks a defined position
TUNE	tunes the 1mm or 3mm receiver
VISI	calculates the rise and set times for sources
VSOURCE	specifies the velocity of a source to observe
WDPLOT	plots the wind directions during the last hour
WHERE	calculates Az/El for given RA/DEC at any LST
WPAGE	displays weather info from ESO station
WSPLOT	plots the wind speeds during the last hour

Appendix B

B.1 Spectral line pointing sources

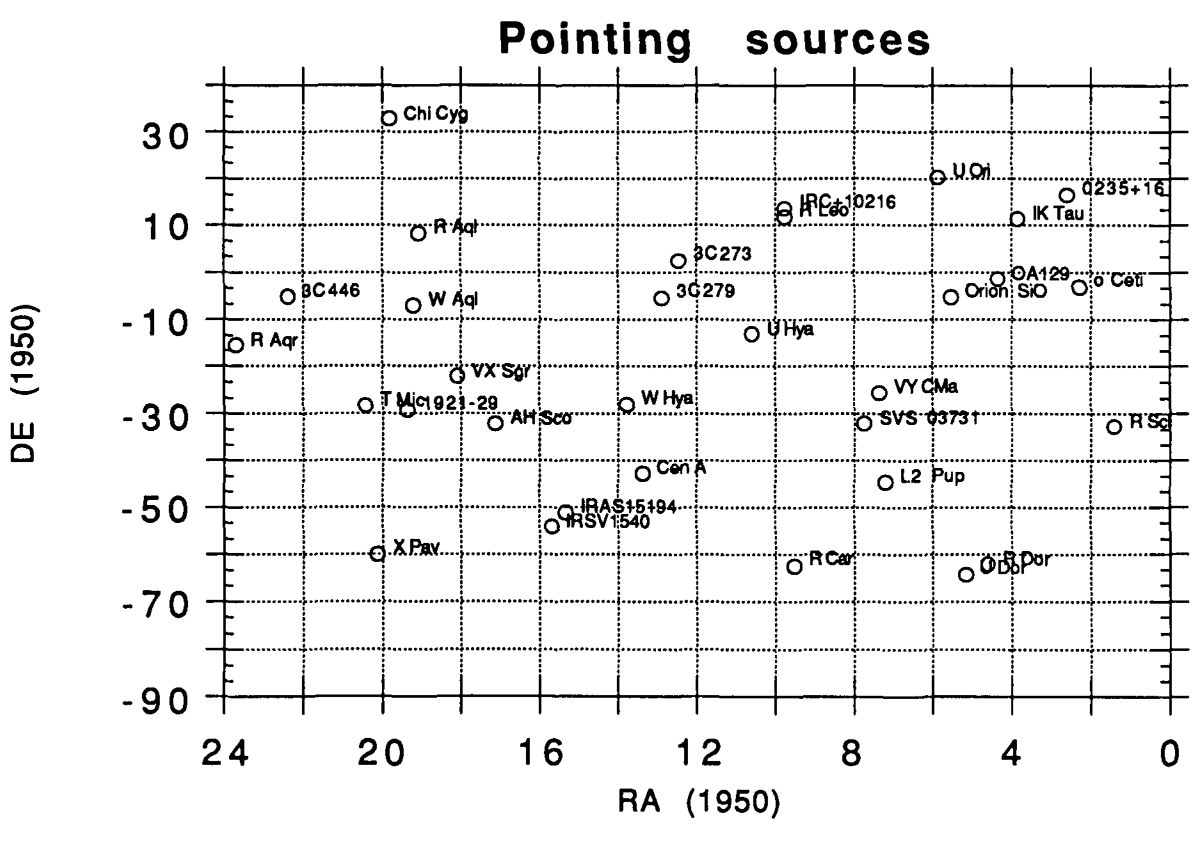

Table B.1: Pointing sources

Source	RA (1950)	De (1950)
Usually bright SiO masers		
o Ceti	02h16m49.0s	−03d12′22.6"
IK Tau	03h50m43.6s	+11d15′32.0"
R Dor	04h36m10.0s	−62d10′34.9"
Orion SiO	05h32m47.0s	−05d24′23.0"
VY CMa	07h20m54.5s	−25d40′11.1"
R Leo	09h44m52.2s	+11d39′40.0"
W Hya	13h46m12.1s	−28d07′08.9"
AH Sco	17h08m01.9s	−32d15′54.0"
VX Sgr	18h05m03.0s	−22d13′54.3"
Chi Cyg	19h48m38.4s	+32d47′10.4"
Bright CO sources		
Source	RA (1950)	De (1950)
IRC+10216	09h45m15.0s	+13d30′45.0"
IRAS15194	15h19m26.9s	−51d15′19.0"
W Aql	19h12m41.7s	−07d08′08.4"
Continuum sources		
Source	RA (1950)	De (1950)
0235+16	02h35m52.6s	+16d24′04.0"
OA129	04h20m43.5s	−01d27′28.0"
3C273	12h26m33.2s	+02d19′43.2"
3C279	12h53m35.8s	−05d31′08.0"
Cen A,	13h22m31.8s	−42d45′30.0"
1921-29	19h21m42.3s	−29d20′27.0"
3C446	22h23m11.1s	−05d12′17.8"
Usually weak SiO masers		
Source	RA (1950)	De (1950)
U Dor	05h09m52.4s	−64d22′50.0"
U Ori	05h52m51.0s	+20d10′05.6"
L2 Pup	07h12m01.1s	−44d33′12.5"
SVS 03731	07h44m38.2s	−32d10′51.0"
R Car	09h30m59.0s	−62d34′00.5"
IRSV1540	15h40m49.2s	−54d13′39.3"
R Aql	19h03m57.7s	+08d09′07.7"
X Pav	20h07m34.5s	−60d05′10.0"
T Mic	20h24m52.3s	−28d25′39.0"
R Aqr	23h41m14.3s	−15d33′42.7"
Weak CO sources		
Source	RA (1950)	De (1950)
R Scl	01h24m40.0s	−32d48′07.0"
U Hya	10h35m05.5s	−13d07′26.0"

B.2 Bolometer pointing sources

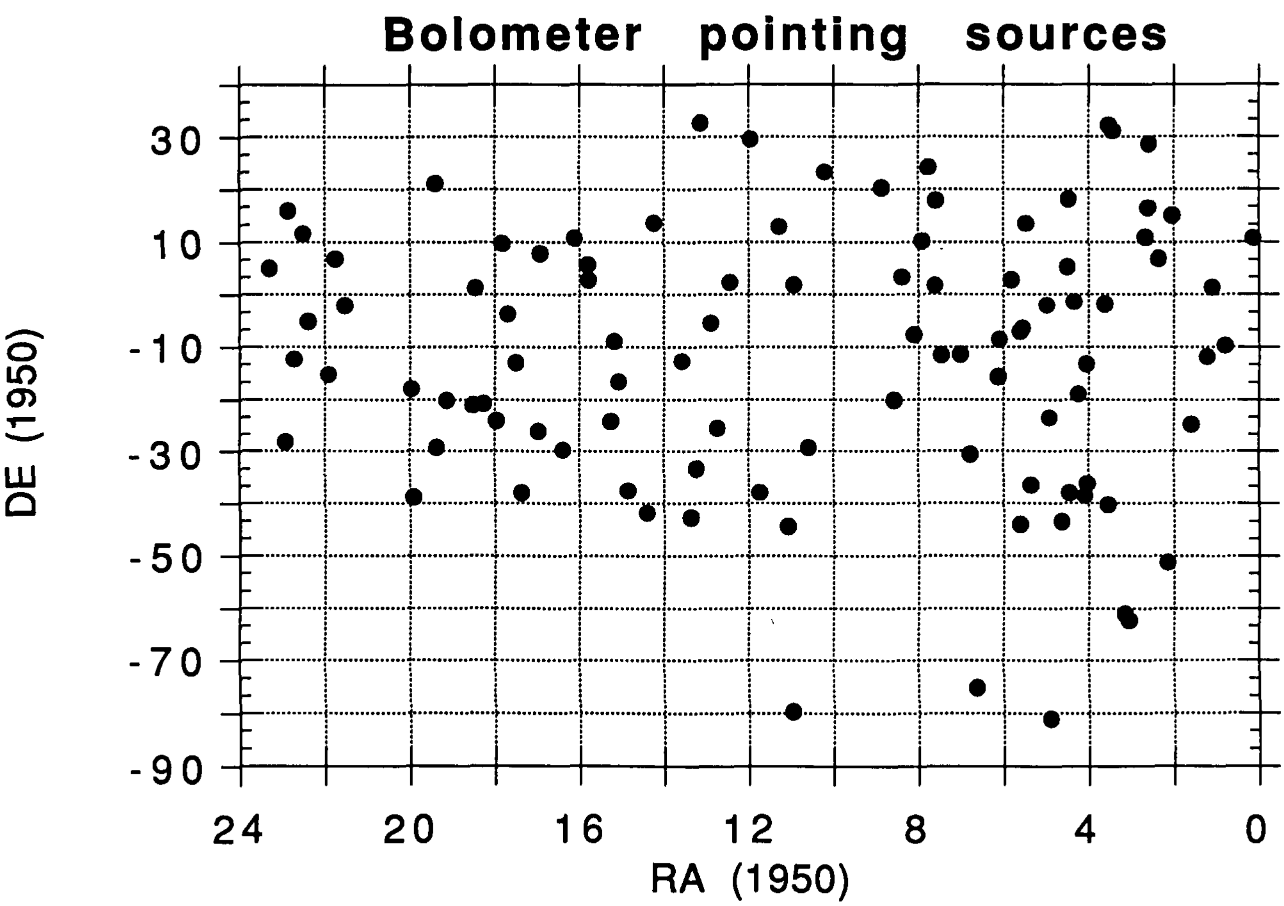

Table B.2: Bolometer pointing sources

		Quasars			
Source	RA (1950)	De (1950)	Aug 90 mJy	Aug 91 mJy	Feb 93 mJy
0007+106	00h07m56.7s	+10d41′48"			430
0048-09	00h48m09.9s	−09d45′24"		900	1500
0106+013	01h06m04.5s	+01d19′01"			800
0113-118	01h13m43.2s	−11d52′05"			450
0135-247	01h35m17.1s	−24d46′09"		1000	430
0202+149	02h02m07.4s	+14d59′51"		1600	840
0208-512	02h08m57.1s	−51d15′08"	2000	1000	
0221+06	02h21m49.9s	+06d45′50"	1000		1400
0234+28	02h34m55.5s	+28d35′12"	1500		1500
0235+16	02h35m52.6s	+16d24′04"	1500		3000
0239+108	02h39m47.1s	+10d48′16"			670
0302-623	03h02m48.4s	−62d23′06"		340	
0308-611	03h08m51.3s	−61d09′59"		300	
0331+321	03h31m40.1s	+32d08′37"		1100	
0332-403	03h32m25.2s	−40d18′23"	500	1300	
0336-019	03h36m59.0s	−01d56′17"	800	1480	1390
0402-362	04h02m02.6s	−36d13′11"	2500	940	
0403-132	04h03m14.0s	−13d16′19"			470
0405-385	04h05m12.7s	−38d34′19"		250	
0414-189	04h14m23.3s	−18d58′28"		250	
0420-014	04h20m43.5s	−01d27′28"	2000	2500	1050
0426-380	04h26m54.7s	−38d02′52"	600	540	
0430+052	04h30m31.6s	+05d14′59"	800		750
0438-43	04h38m43.2s	−43d38′54"	550	280	
0454-81	04h54m17.5s	−81d05′55"	500	530	
0454-234	04h54m57.3s	−23d29′29"			640
0458-020	04h58m41.3s	−02d03′33"	650		810
0521-365	05h21m12.9s	−36d30′17"	1500	1480	
0528+134	05h28m06.8s	+13d29′42"	800	2800	3450
0537-441	05h37m21.1s	−44d06′45"	1300	1671	
0605-085	06h05m36.0s	−08d34′20"	1100		
0607-157	06h07m26.0s	−15d42′03"	1200		
0637-75	06h37m23.3s	−75d13′34"	2700	1562	
0646-306	06h46m19.6s	−30d40′54"	400	296	
0727-115	07h27m58.5s	−11d34′53"	1800	1410	
0735+178	07h35m14.1s	+17d49′09"	1000	1910	690

Table B.3: Bolometer pointing sources

Source	RA (1950)	De (1950)	Aug 90	Aug 91	Feb 93
		Quasars			
			mJy	mJy	mJy
0736+017	07h36m42.5s	+01d44′00″	1200	520	650
0745+241	07h45m35.7s	+24d07′55″		570	430
0754+100	07h54m22.6s	+10d04′40″		700	570
0805-078	08h05m49.6s	−07d42′23″		670	490
0823+033	08h23m13.6s	+03d19′16″	900	1700	770
0834-201	08h34m24.6s	−20d06′30″		660	470
0851+202	08h51m57.3s	+20d17′58″	4000	1350	1100
1012+232	10h12m00.5s	+23d16′12″		380	450
1034-293	10h34m55.9s	−29d18′28″	1000	390	2320
1055+018	10h55m55.3s	+01d50′04″	1300	2050	1030
1057-79	10h57m50.3s	−79d47′39″	680		
1104-445	11h04m50.4s	−44d32′53″	1000		
1116+128	11h16m20.8s	+12d51′07″	1150	500	290
1144-379	11h44m30.9s	−37d55′31″	1200		
1156+295	11h56m57.8s	+29d31′26″	1180	490	950
1226+023	12h26m33.3s	+02d19′43″	10000	11110	12700
1244-255	12h44m06.7s	−25d31′27″		1100	590
1253-055	12h53m35.8s	−05d31′08″	4500	11300	6600
1308+326	13h08m07.6s	+32d36′40″		930	1260
1313-333	13h13m20.1s	−33d23′10″		2800	3680
1322-428	13h22m31.5s	−42d45′32″	8200		
1334-127	13h34m59.8s	−12d42′10″	4700	3550	2990
1413+135	14h13m33.9s	+13d34′17″		1200	230
1424-418	14h24m46.5s	−41d52′52″	600		
1451-375	14h51m18.3s	−37d35′22″	1150		
1504-167	15h04m16.5s	−16d40′58″		465	
1510-089	15h10m08.9s	−08d54′48″	3000	1289	740
1514-241	15h14m45.3s	−24d11′22″	600		
1546+027	15h46m58.3s	+02d46′06″	1640	520	1760
1548+056	15h48m06.9s	+05d36′12″	800	250	
1606+106	16h06m23.4s	+10d36′59″			310
1622-297	16h22m57.3s	−29d44′41″	400		1650
1655+077	16h55m43.9s	+07d45′59″	1000	370	340
1657-261	16h57m47.7s	−26d06′29″	1700	1500	650
1730-130	17h30m13.5s	−13d02′46″	4000	3500	3870

Table B.4: Bolometer pointing sources

Quasars

Source	RA (1950)	De (1950)	Aug 90 mJy	Aug 91 mJy	Feb 93 mJy
1741-038	17h41m20.6s	−03d48′49”		1230	1030
1749+096	17h49m10.4s	+09d39′43”	1500	1800	5040
1757-240	17h57m26.8s	−24d03′57”		14000	
1830-211	18h30m40.6s	−21d06′00”		1020	720
1908-202	19h08m12.5s	−20d11′55”		1000	870
1921-293	19h21m42.3s	−29d20′27”	4000	8600	7150
1923+210	19h23m49.8s	+21d00′23”		350	690
1954-388	19h54m39.0s	−38d53′13”	1200	978	
1958-179	19h58m04.6s	−17d57′16”	2500	1000	
2131-02	21h31m35.3s	−02d06′41”	500		
2145+067	21h45m36.1s	+06d43′41”	3000	2300	2130
2155-15	21h55m23.2s	−15d15′32”	460		
2223-052	22h23m11.1s	−05d12′18”	2500	1450	
2230+114	22h30m07.8s	+11d28′23”		1500	1170
2243-123	22h43m39.8s	−12d22′41”	1000	1130	
2251+158	22h51m29.5s	+15d52′54”	4000	3720	
2255-282	22h55m22.3s	−28d14′22”	1500		
2318+094	23h18m12.1s	+04d57′23”	1000		

HH–objects and young stellar objects

Source	RA (1950)	De (1950)	mJy
HH7-11	03h25m58.1s	+31d05′45”	1229
HH28-29	04h28m40.2s	+18d01′41”	1569
HH34	05h33m03.7s	−06d28′53”	335
V883 Ori	05h35m52.6s	−07d04′06”	550
HH111	05h49m09.3s	+02d47′48”	452
Z Cma	07h01m22.5s	−11d28′36”	446
17216-3801	17h21m40.9s	−38d01′23”	ca2000
HH8-81	18h16m13.0s	−20d48′48”	2340
Serpens	18h27m17.4s	+01d13′16”	2100

Appendix C

C.1 SEST line calibration sources

The following sources are used as line calibrator sources at SEST. A binder containing the spectra is available in the SEST control room.

Table C.1: SEST calibration sources

Source	RA (1950)	De (1950)
Orion SiO	05h32m47.0s	−05d24′23"
IRC+10216	09h45m15.0s	+13d30′45"
IRAS15194	15h19m26.9s	−51d15′19"
M17SW	18h17m30.0s	−16d13′00"

Appendix D

D.1 SEST FITS-header

SIMPLE	=	T	/STANDARD FITS FORMAT, SEST VERSION 2.0
BITPIX	=	16	/NUMBER OF BITS PER PIXELS
NAXIS	=	3	/NUMBER OF COORDINATE AXES
NAXIS1	=	2000	/NUMBER OF PIXELS PER AXIS
NAXIS2	=	1	/NUMBER OF PIXELS PER AXIS
NAXIS3	=	1	/NUMBER OF PIXELS PER AXIS
BSCALE	=	3.8763071643189E-05	/CONVERSION FACTOR FROM UNIT ON TAPE
BZERO	=	1.0431129932404E00	/CONVERSION CONSTANT FROM UNIT ON TAPE
BUNIT	=	'K '	/BRIGHTNESS UNIT
BLANK	=	-32768.0	/TAPE VALUE FOR UNDEFINED PIXEL
CTYPE1	=	'FREQ '	/TYPE OF COORDINATE UNIT
CRVAL1	=	0.0000000000000E00	/X-COORDINATE
CDELT1	=	4.3100992187500E04	/PIXEL INTERVAL (SIGN IMPLIES DIRECTION)
CRPIX1	=	1.0010000000000E03	/REFERENCE PIXEL
CTYPE2	=	'RA '	/TYPE OF COORDINATE UNIT
CRVAL2	=	1.4631246948242E02	/X-COORDINATE
CDELT2	=	0.0000000000000E00	/PIXEL INTERVAL (SIGN IMPLIES DIRECTION)
CRPIX2	=	0.0000000000000E00	/REFERENCE PIXEL
CTYPE3	=	'DEC '	/TYPE OF COORDINATE UNIT
CRVAL3	=	1.3512498855591E01	/X-COORDINATE
CDELT3	=	0.0000000000000E00	/PIXEL INTERVAL (SIGN IMPLIES DIRECTION)
CRPIX3	=	0.0000000000000E00	/REFERENCE PIXEL
TELESCOP	=	'SEST 15M'	/TELESCOPE USED
ORIGIN	=	'LA SILLA'	/PLACE OF ORIGIN
OBJECT	=	'IRC+10216 '	/NAME OF THE ASTRONOMICAL OBJECT
LINE	=	'CN 1-0 J=3/2'	/NAME OF MOLECULAR LINE
OBSERVER	=	'G.Persson '	/NAME OF OBSERVER
GLON	=	2.2144531250000E02	/GALACTIC LONGITUDE IN DEGREES
GLAT	=	4.5061294555664E01	/GALACTIC LATITUDE IN DEGREES
INDX	=	2.2783416748047E01	/HORIZONTAL AZIMUTH IN DEGREES
INDY	=	4.4920806884766E01	/HORIZONTAL ELEVATION IN DEGREES
EPOCH	=	1.9500000000000E03	/EPOCH OF COORDINATES USED
BLANK	=	1.8070034443440E-16	/BLANKING VALUE
RESTFREQ	=	1.1350894400000E11	/REST FREQUENCY IN HZ
IMAGFREQ	=	0.0000000000000E00	/IMAGE FREQUENCY IN HZ
CENTFREQ	=	1.1351606249046E11	/SKY FREQUENCY IN HZ
VLSR	=	-2.6200000762939E04	/LSR VELOCITY OF REFERENCE CHANNEL M/S
DELTAV	=	-1.1382843554020E02	/VELOCITY RESOLUTION IN M/S
TSYS	=	4.4787500000000E02	/SYSTEM TEMPERATURE IN K
OBSTIME	=	7.2000000000000E02	/INTEGRATION TIME IN SECONDS
SCAN-NUM	=	1.0000000000000E03	/SCAN NUMBER
TAU-ATM	=	1.5445438027382E-01	/ATMOSPHERIC OPACITY IN NEPER
TAMB	=	2.8890002441406E02	/AIR TEMPERATURE IN K
PRESSURE	=	7.7329986572266E01	/AIR PRESSURE IN KPA
HUMIDITY	=	2.9000000000000E01	/RELATIVE AIR HUMIDITY IN %
NPHASE	=	0	/NUMBER OF FREQUENCY PHASES
DATE-OBS	=	'15/02/91'	/DATE OF OBSERVATION
DATE	=	'16/02/91'	/DATE OF TAPE CREATION
UTC	=	'03:50:37'	/UTC OF OBSERVATION
END			