Chapter 5

Electronics

This chapter describes the electronics of the water vapour monitors. The underlying principle is that of any high frequency receiver: a high frequency signal at a few hundred GHz (receiver frequency RF) is mixed down to an intermediate frequency (IF) signal at a few GHz, amplified and detected. A computer digitises and stores the detected signal. However, the specific design, the components chosen and detailed layout are unique to the water vapour monitors.

In this chapter I will first (§5.1) state the requirements of the radiometers and quickly mention how they influenced our design. Secondly (§5.2), a brief overview of the electronic set-up is given followed by a more detailed discussion of some of the electronic components which were specifically chosen for our application. Section §5.3 outlines the temperature regulation of the electronics. The computer set-up, which runs the water vapour monitors and takes and stores the data, is described in §5.4. At the end of the chapter (§5.5) the performance of the radiometers is summarised.

5.1 Requirements

Here is a list of requirements which influenced the design of the water vapour monitors:

1. Sensitivity

   We aim to reduce the phase fluctuations due to water vapour to 18° at 500 GHz, in

order to limit the loss of the astronomical signal due to decorrelation to 10 % ($(\sin 18)^2$). Therefore we need to determine the difference in optical path length between the two telescopes to c/500 GHz$\times 18^\circ/360^\circ = 30\mu m$ rms, and the optical path for each telescope to $21\mu m$ ($= 30\mu m/\sqrt{2}$). As explained in §3.3.4 the sensitivity $\Delta T/\Delta L$, i.e. the change in brightness temperature ΔT given a change in optical path length ΔL is not constant but depends on the saturation of the water line and on the measuring frequency. Assuming an average sensitivity of 10 K/mm for channel 1, a change in optical path of $21\mu m$ corresponds to a change in brightness temperature of 0.2 K.
→ The brightness temperature should be measured to an accuracy of 0.2 K.
→ For an IF bandwidth of 200 MHz and an integration time of 1 second a system temperature of 2500 K yields a theoretical sensitivity of 0.18 K, which is sufficient for our application. Therefore we can afford to have an uncooled system with a noise temperature around 2500 K.

2. Stability

   Besides reducing the noise as far as possible, the gain between the input signal and the detector output needs to be constant or at least well known.
   → The electronic components have been selected to be insensitive to temperature changes, especially the detectors.
   → In addition the electronics are kept at a constant temperature, as the gain of amplifiers varies with temperature. Heaters and fans were implemented for this purpose.
   → Frequent calibrations (one per second) are performed to determine the gain.

3. Frequency passband

   The frequency bands must be well determined, i.e. the width of the passband as well as its frequency:
   → A phase lock loop (PLL) insures that the local oscillator (LO) frequency stays constant.
   → The LO operates at the centre frequency of the emission line. Since a double sideband measurement is taken, a slight increase in the LO frequency results in a decrease in brightness on the low frequency side, but an increase in the brightness temperature on

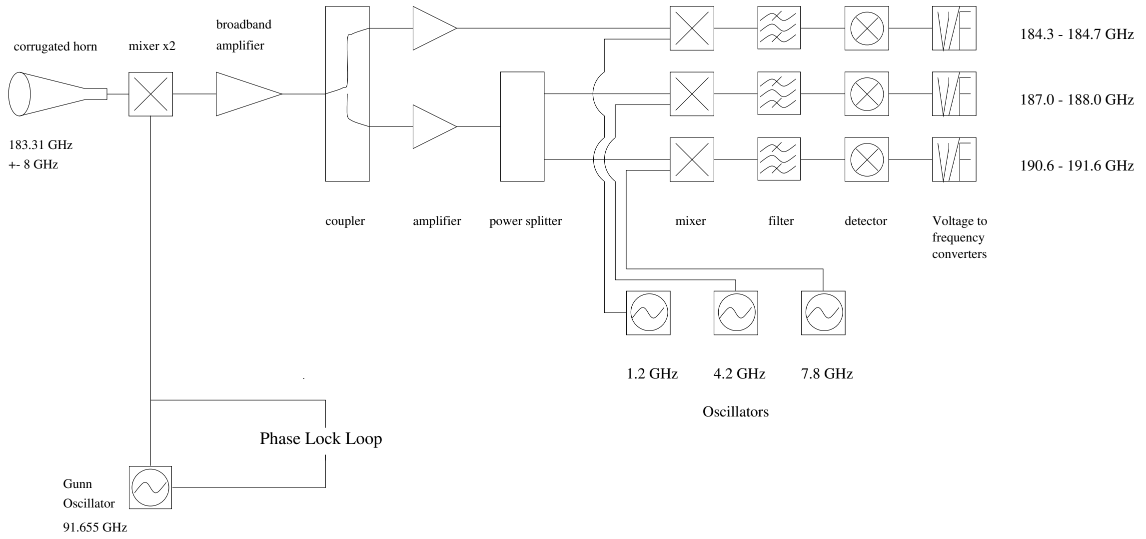

Figure 5.1. Schematics of WVM electronics.

the high frequency side. To first approximation the sum of the signals stays constant.
→ In order to determine the frequency band accurately the signal is mixed down a second time and then passed through low pass filters (see §5.2.2).

4. Easy maintenance and low cost
   Last but not least we wanted to keep the construction and the maintenance of the water vapour monitors simple and low cost:
   → Neither the electronics nor the calibration loads are cooled.
   → The Gunn oscillator (Gunn) works at a fixed frequency.

5.2 Description of electronics

According to the requirements stated above we designed and realized the circuit shown in Fig. 5.1. The radiation emitted by the atmospheric water vapour passes through an arrangement of mirrors and is focussed on the horn (see chapter on WVM optics §4). The subharmonic double sideband mixer multiplies the second harmonic of the LO (i.e. a signal

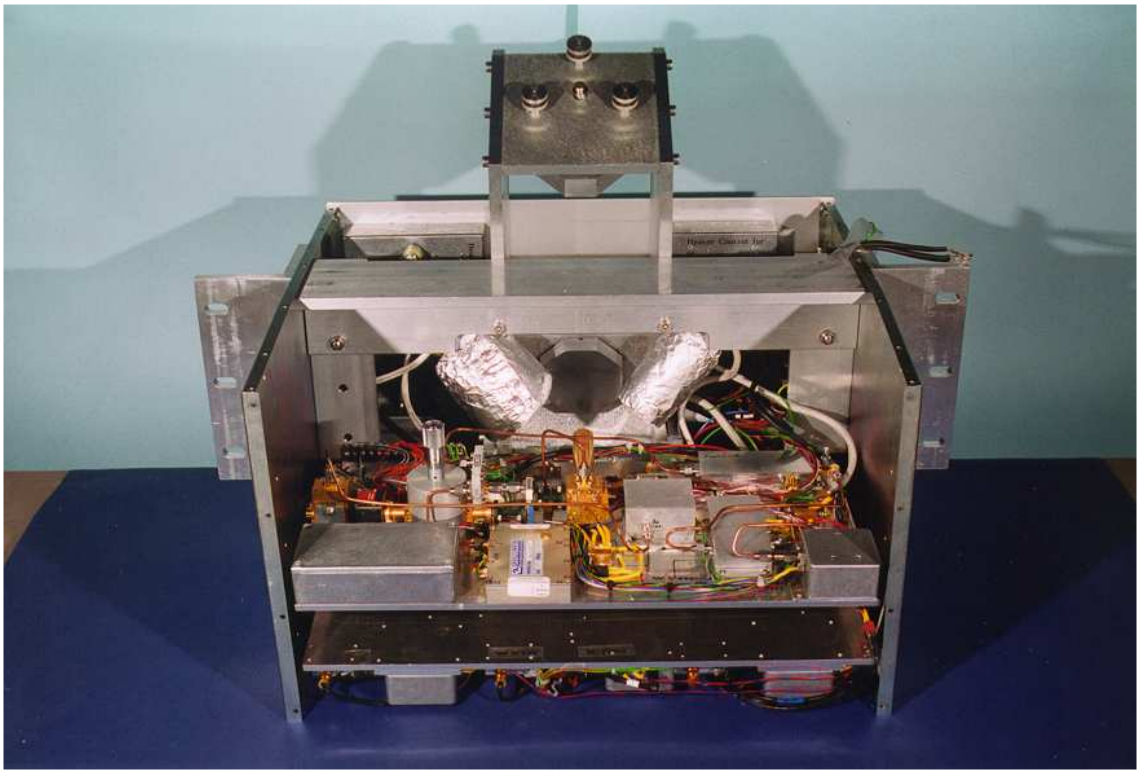

Figure 5.2. The WVM box with the two electronics plates. The upper plate is the RF plate. The horn and mixer are in the centre of the RF plate, the horn is pointing away from the photographer to mirror M1. The lower plate contains the IF electronics.

at twice the LO frequency) with the incoming signal. The signal at the difference frequency, the intermediate frequency (IF), is amplified and then passed to the IF plate, where it is split into three and amplified again. Each branch of the signal is mixed a second time with an oscillator signal at 1.2, 4.2 and 7.8 GHz respectively. Each of the resulting signals passes through a low frequency filter and is measured in a Schottky detector. The voltage to frequency converters (V/F converters) transform the output voltages into frequencies. These frequencies are transmitted to a computer, where they are counted and converted into digital signals, which are further processed.

Physically the electronics is mounted on two temperature regulated aluminum plates. The "RF plate" contains the receiver frequency (RF) components and the first broadband amplifier (Fig. 5.3 and 5.4). The "IF plate" with the intermediate frequency (IF) components

R.F. Plate

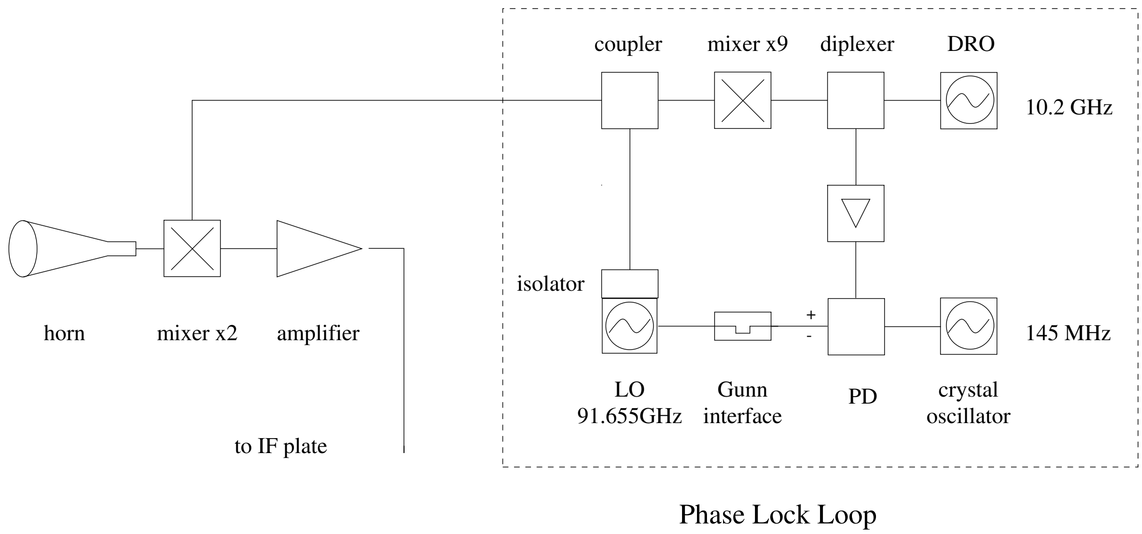

Figure 5.3. Receiver frequency (RF) electronics.

(Fig. 5.5 and 5.6) is located upside down under the "RF plate". Fig. 5.2 shows a picture of a water vapour monitor with the two plates. I will now discuss some of the components in more detail.

5.2.1 RF plate

Horn: The horn focuses the sky signal and passes it through a waveguide to the mixer. To avoid any current flow along its surface the 76 mm long horn is corrugated, i.e. ∼0.5 mm wide rings are carved in the inside of the horn. Colleagues from the Rutherford Appleton Laboratory (RAL) built the two corrugated horns.

Mixer: The mixer mixes the signal from the Gunn oscillator and the sky to to an intermediate frequency (IF), which is much easier to work with. One can think of the mixer as lowering the RF signal by subtracting the constant frequency produced by the Gunn. Each water vapour monitor uses a double sideband subharmonically pumped mixer built by RAL. Double sideband means that both the upper and lower sidebands (e.g. 183+5 GHz and 183-5 GHz) are mixed down and contribute to the IF (5 GHz). A subharmonically pumped mixer doubles the Gunn frequency before subtracting the

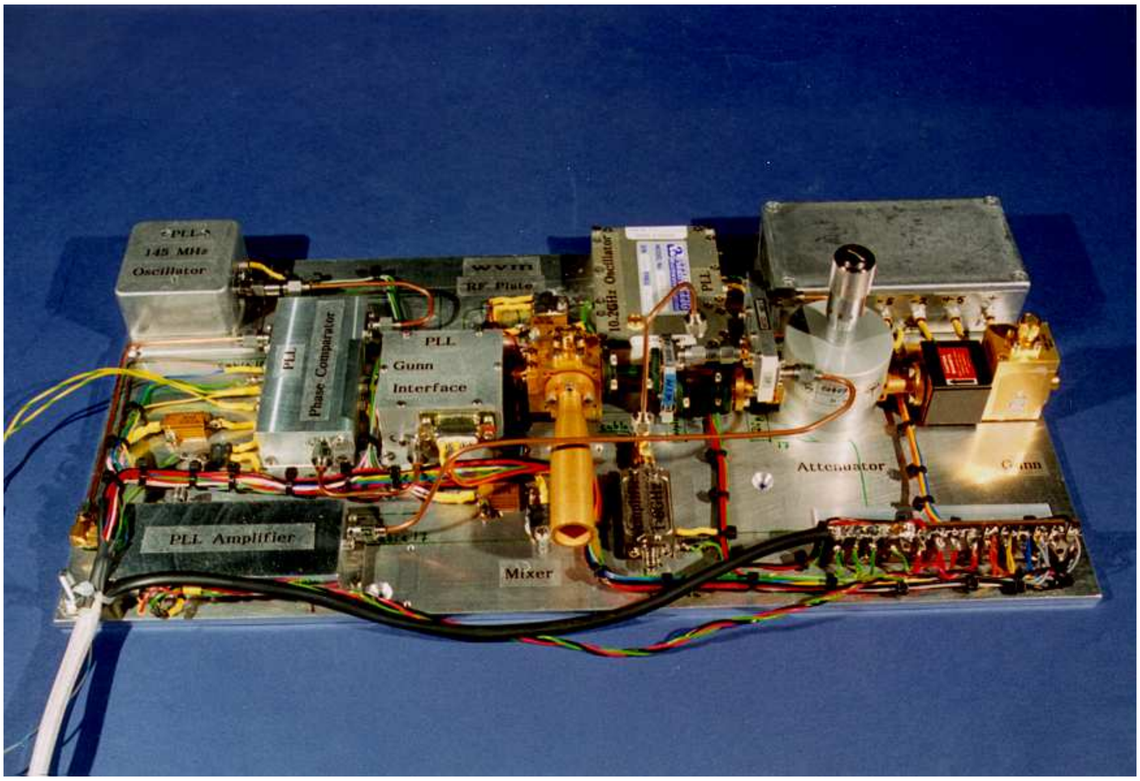

Figure 5.4. Picture of RF electronics.The horn is in the middle pointing towards the photographer. Just behind the horn is the mixer. The Gunn is on the very right of the plate, left of it is the cylindrical attenuator with a micrometer screw for tuning. On the left of the mixer are the different components of the PLL. The first stage broad band amplifier is in the foreground on the right of the horn.

RF. The mixers always operate at the same frequency so can be fixed tuned. Horn and mixers together have a noise temperature of about 1500 K - 2600 K depending on the frequency.

Gunn oscillator: The commercial Gunn oscillator, also called local oscillator (LO), operates at exactly half the centre frequency of the water line, i.e. at 91.665 GHz. By choosing this frequency and using a subharmonic double sideband mixer, small shifts in the oscillator frequency should not change the output dramatically, see 5.5.2.

Phase lock loop (PLL): The basic task of the phase lock loop is to ensure that the LO frequency does not change, but it also keeps the conversion (i.e. mixing capability) of the mixer constant. 10 dB [1] of the LO signal is coupled out before the mixer. This signal is mixed with a harmonic of a stable fixed frequency reference oscillator. In our case the ninth harmonic of 10.2 GHz produced by a dielectric resonance oscillator (DRO) is mixed with the LO signal. The difference between the two oscillator frequencies should be 145 MHz ($9 \times 10.2 - 91.655$ GHz). This difference is amplified and then compared to a very stable 145 MHz crystal oscillator in the phase detector (PD). If there is a difference between the two frequencies the PD produces a voltage proportional to this difference, which is added to the voltage driving the Gunn. A change in supply voltage will make the Gunn oscillate at a slightly different frequency. In this way the LO frequency is constantly monitored and adjusted.

Broad band amplifier: The first amplifier after the mixer is a commercial, low noise, broad band amplifier. It is important that there is little noise added by this amplifier, especially because the mixer has a conversion loss of about 7 dB, so that the sky signal is reduced by a factor of 0.2. The amplifier enhances the sky signal as well as any noise. (One can think of the system temperature being increase by a factor of 1/0.2 due to the loss in the mixer.) Once the signal from the sky has been amplified, added noise will usually only constitute a small percentage of the signal and not be of great importance. Since the radiometer probes the water line at several frequencies in the line wing (but not at the line centre) the amplifier needs to cover a frequency range from around 1 to 8 GHz (broad band). We choose an amplifier of nearly constant gain

[1] A deci Bell (dB) is defined as a ratio of power P_1 and P_2 such that x dB is equivalent to $\frac{P_1}{P_2} = 10^{-\frac{x}{10}}$.

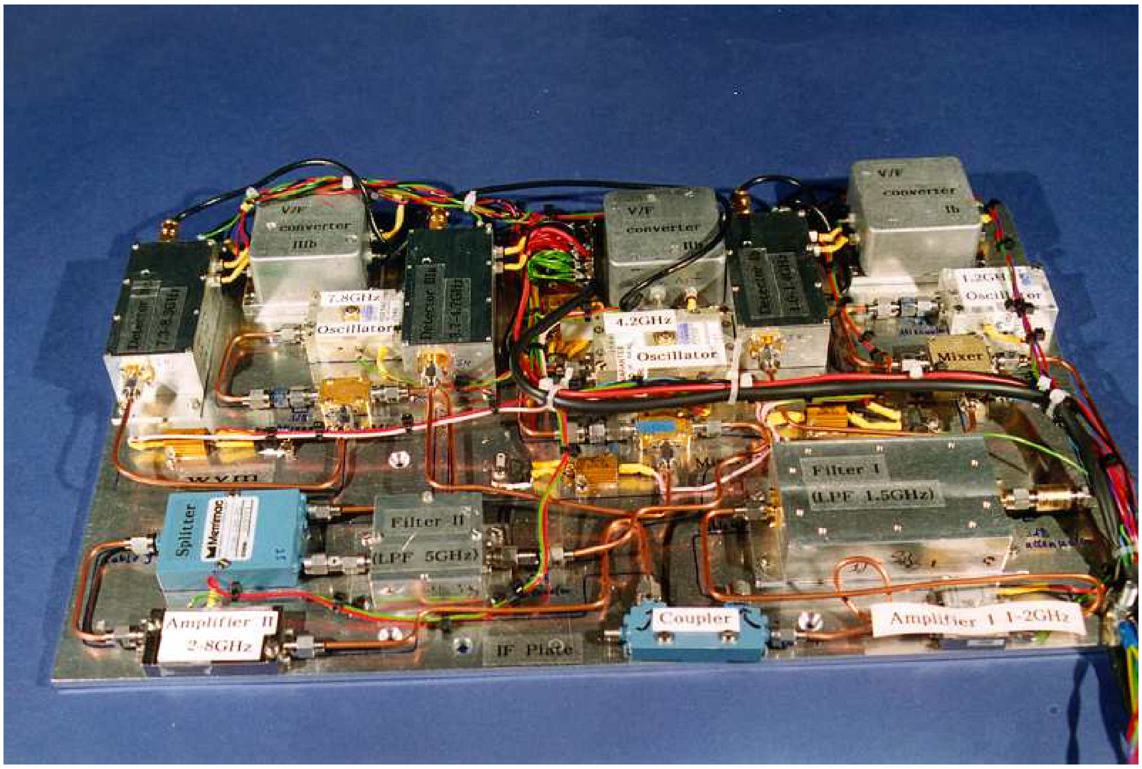

Figure 5.5. Picture of IF electronics. The signal from the RF plate enters the coupler in the middle of the foreground and is then split and down converted. The three crystal oscillators and mixers for the second down conversion are in the middle of the plate. The three elongated, dark boxes in the background are the detectors for the three channels. On the right of each detector is a square box containing the voltage to frequency converters.

within each frequency band, because we do not want certain frequencies within a band to be preferentially amplified (also see §5.2.2).

5.2.2 IF plate

Coupler and Splitter: The coupler and power splitter are used to divide the sky signal into three parts, each covering the whole IF range. From each part a different frequency band is filtered out for further processing.

An alternative to just dividing the signal in power would be to use a triplexer, which selects the signal according to its frequency. The 1 - 8 GHz IF signal would, for example,

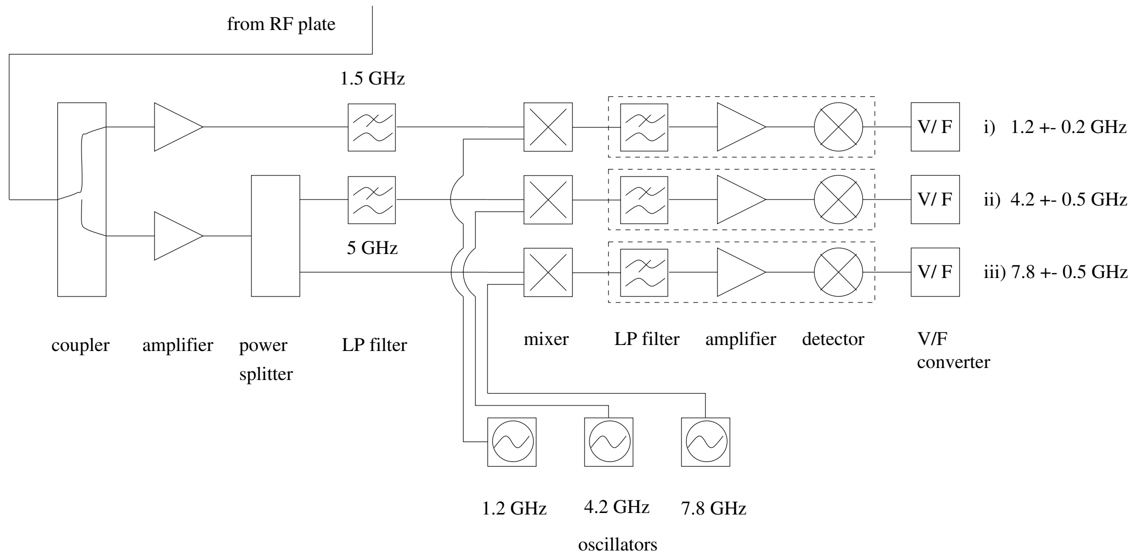

Figure 5.6. Intermediate frequency (IF) electronics.

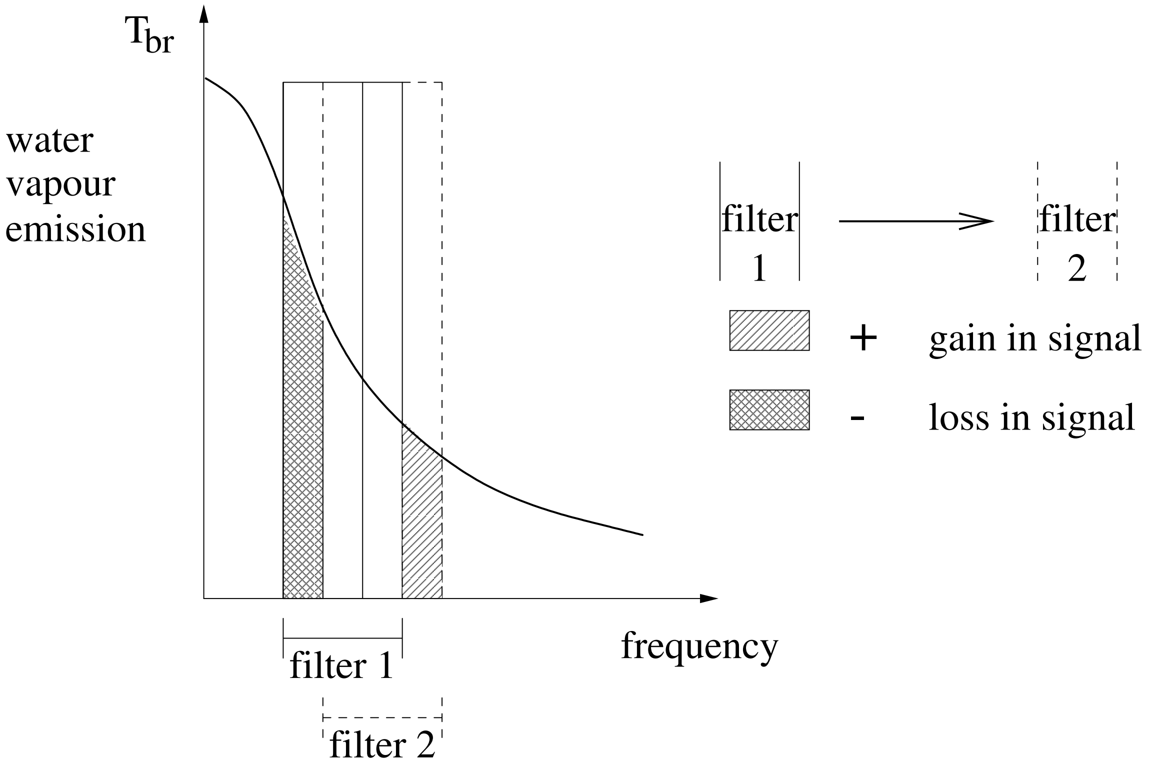

Figure 5.7. A small shift in the centre frequency of a filter results in a big change in the measured brightness temperature because the water line is very steep.

be split into a channel covering 1.0 - 1.4 GHz, another covering 3.7 - 4.7 GHz and a third of 7.3 - 8.3 GHz. By using a triplexer no signal is lost (as it is in the power splitter and filter set-up). However, suitable triplexers are very expensive. More importantly, in order to measure a optical path difference of $30\mu m$ the frequency bands of the triplexer need to be known to better than 5 MHz. At least the triplexers used in each of the two radiometer need to be the same within 5 MHz (see Fig. 5.7). None of the commercially available triplexers had this accuracy.

Second down conversion: Instead of passing the three IF channels through three different filters, which pass the desired frequency bands, the IF signal is down-converted a second time: The signal in the first channel is mixed with a coaxial resonator oscillator signal at 1.2 GHz. The difference frequency is then passed through a 200 MHz wide low pass filter. Since the mixer is double side band the first channel covers a frequency range of

1.0 to 1.4 GHz above and below the centre of the water line at 183.3 GHz. The second channel is mixed with a dielectric resonator oscillator at 4.2 GHz, the third with one at 7.8 GHz, and each is passed through a 500 MHz low pass filter.
The second down conversion has two big advantages:

1. The positions of the frequency bands are well defined, as it is easy to buy oscillators with an accuracy of $\Delta\nu/\nu \leq 10^{-5}$, i.e. the frequency is defined to better than 0.1 MHz.

2. No knowledge of the shape of the filter bandpass is required.

   To explain this I would like to consider first a system without a second down conversion, where the filter would sit on the wing of the steep water line (Fig. 5.7) and the intensity passed by the filter will depend on the shape of the bandpass: A filter with preferred transmission at low frequencies will pass most of the high intensity line emission but little of the low intensity emission, whereas a filter preferentially passing high frequencies will filter out some of the high intensity emission. As a result the latter filter will pass less intensity than the first. However, when observing a calibrator, which is usually a black body and effectively has constant intensity over the small bandwidth of the filter, the detected intensity will be independent of the shape of the bandpass, but will only depend on the integral of passband over frequency. Therefore the two filters discussed above would give the same output intensity when looking at a calibrator, but different intensities when looking at the line.

   However, if there is a second down conversion, the water line is folded at the oscillator frequency (Fig. 5.8). To first approximation the double sideband signal is flat, just as that of the calibrator, and the shape of the filter becomes irrelevant. Only the integrated bandpass is of interest, which can be easily determined using a black body as a calibrator. [2]

Filtering out harmonics of crystal oscillators: For the second down conversion a set of three oscillators is used. In order to avoid any harmonics (i.e. whole multiples of the oscillator frequency) appearing as spurious signals in the measurements, the frequency

[2] Using the same argument the gain of amplifiers after the second down conversion is of no importance, however the gain of amplifiers before the mixing needs be flat.

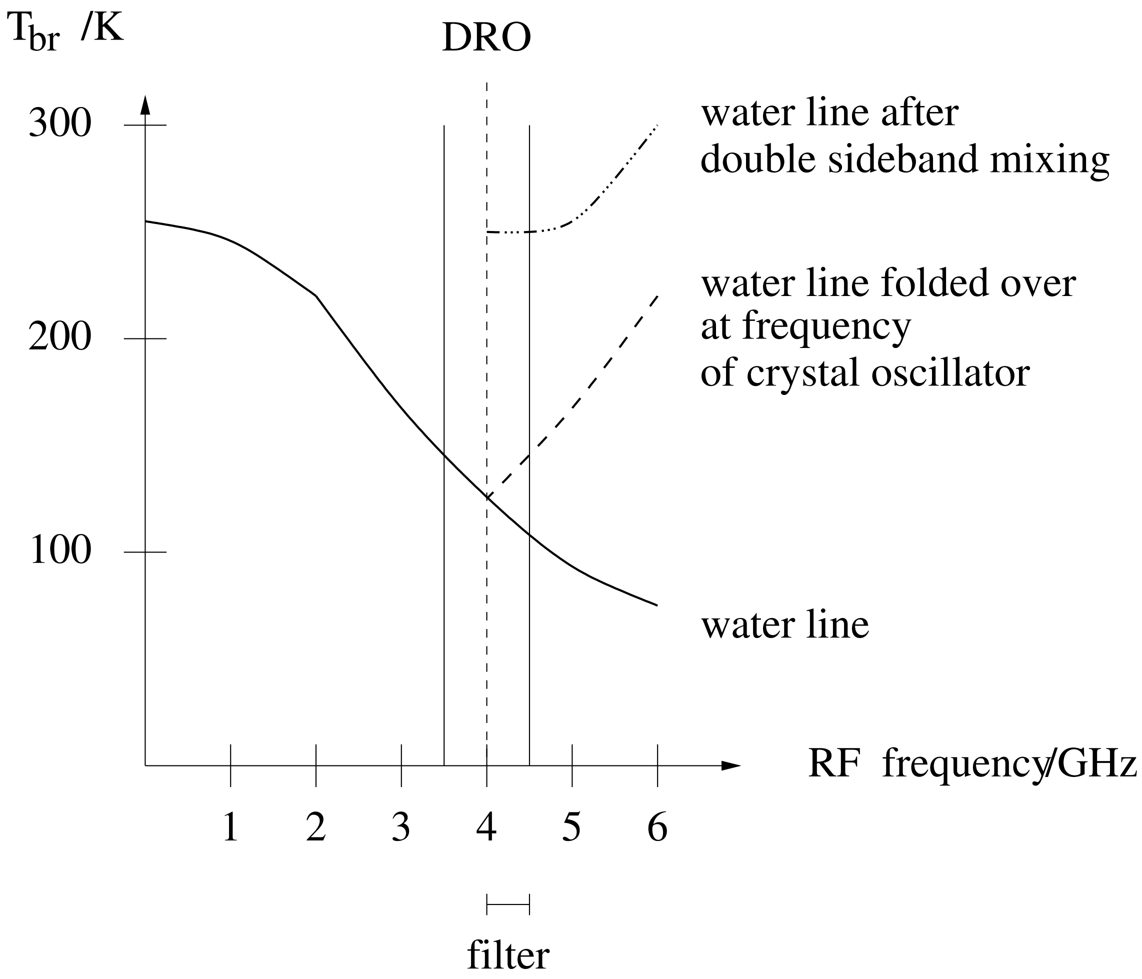

Figure 5.8. Double sideband mixing of the water line with a dielectric resonator oscillator (DRO) signal at 4 GHz. The water vapour line is folded at 4 GHz and the original line and the folded line are added. The sum of the signals will be flat, as long as the original line can be approximated by a tangent and the upper and lower sideband response are the same, i.e. the sum is not weighted.

bands are chosen so that any harmonics lie outside them. E.g. the sixth harmonic of 1.2 GHz falls outside the frequency range of the third channel of 7.3 to 8.3 GHz, and the seventh harmonic of 1.2 GHz as well as the second of 4.2 GHz are above 8.3 GHz. In addition a 1.5 GHz low pass filter was added between the second amplifier and the mixer to prevent any harmonics of the 1.2 GHz oscillator to travel backwards through the amplifiers and the coupler into the second or third channel. Similarly a 5 GHz low pass filter to stop harmonics of the 4.2 GHz oscillator was used (see Fig. 5.6).

Detector: The signal in each channel is measured by a Schottky diode detector (level detector). The voltage across the diode is determined by the input current, consisting of a constant bias current and the signal. This voltage is amplified and used to determine the intensity of the signal input. However, temperature changes in the diode can change the voltage across the diode with the current being constant. In order to eliminate temperature effects the voltage across a second diode, whose only input is the bias current, is subtracted from the voltage of the detector diode. Temperate changes will cause both diode outputs to change by the same amount. The voltage difference should therefore only depend on the signal input and the output signal is temperature independent.

It was observed that the detector output is not linearly proportional to the input brightness temperature. Instead the detected voltage V is proportional to the input brightness temperature T_{bri} to the power of β, $V(T_{bri}) = aT_{bri}^{\beta}$. β takes values between 0.8 and 1. However, since we are interested in brightness temperature changes in a very small regime $\leq 10\ K$ compared to the input brightness temperature T_0 of $\sim 2500K$ $V(T_{bri})$ can be approximated by its tangent at T_0. This approximation will lead to an error in the difference temperature of less than 1%.

Voltage to frequency converters and signal transmission: As it is difficult to measure the detector output voltage accurately to 10^{-4} with a voltmeter, the voltage is converted into a frequency (with a constant conversion factor of about 180 kHz/1 V). This frequency is sent to a computer, where it is counted and digitised. In order to avoid interference each frequency is transmitted differentially along a shielded pair of twisted wires: each wire is at about 2.5 V. The frequency is transmitted by a rise in voltage to 3.5 V on one wire and simultaneously decrease to 1.5 V on the other wire. Since the voltage of the two wires changes at the same time, but in opposite sense, the far field of the wire pair will be the same as that of a wire constantly at 2.5 V. A constant field does not emit radiation, hence the transmitted signal should not cause any interference.

Optoisolators: Each pair of twisted wires is connected to an optoisolator at the computer end, to decouple the water vapour monitor electrically from the computer. The current induced by the changing voltage lights a small light emitting diode (LED) at the frequency of the V/F converter output. A detector sees the light pulses and sends a signal to the counter board in the computer. The optoisolator faithfully reproduces the signal frequency but at a constant output amplitude optimised for the counter board. Therefore voltage spikes won't harm the computer. In addition the radiometer and the computer can be connected to different ground voltages.

5.3 Temperature regulation

Many of the electronic components are quite sensitive to temperature changes. If the temperature of our RF plate rises by 1 Kelvin, the voltage output of the detectors decreases by 0.5 %. For the IF plate a temperature rise of 1 K, reduces the output by 0.5 to 1.0 % depending on the frequency channel. In order to measure brightness temperature fluctuations of 0.5 K in a system temperature of about 2500 K, we need to measure fluctuations of the order of 0.05 % of the output signal. Besides frequently calibrating the radiometers (once a second), all the electronic components are temperature regulated. Temperature sensors and heaters are mounted on the aluminum plates and two fans circulate the air in the electronic box.

Heaters: Four heaters (transistors and resistors) are located on each of the aluminum plates, on which the electronic components are mounted. Sensors in the centre of the plates monitor the temperature and regulate the heater current. The RF plate is heated to $\sim 40^\circ$ C, the IF to $\sim 38^\circ$ C. In both cases this temperature lies slightly above the temperature to which the electronics warms up without heaters.

Fans: Each water vapour monitor box contains two fans, one for circulating the air inside the box, the other to extract hot air.
The first fan runs constantly ensuring that the air is well mixed. Regions of hotter air could otherwise form and would shift in an uncontrolled way when the telescope and

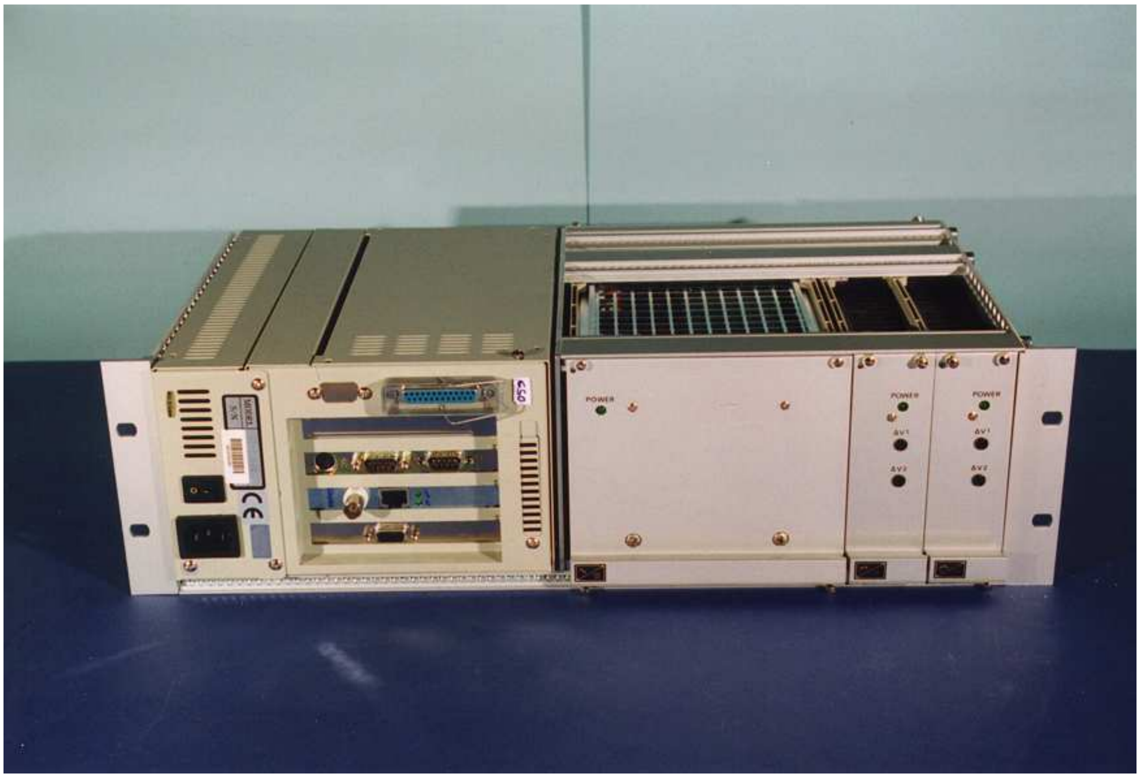

Figure 5.9. Industrial PC (left) and power unit (right) for WVMs in a two units high (~ 90 mm) 19 inch rack. The PC drives drives the flip mirror and digitises the data. The power unit supplies +15 V and -15V for the IF and RF electronic components and 26 V for the heaters.

therefore the WVM is tipped.
The extractor fan is coupled to the heating circuit of the RF plate since it is more likely to overheat than the IF plate. The voltage driving the fan is inversely proportional to that of the heaters. The extractor fan is turned off when the heaters are running at full power, but it slowly turns on as the plate gets close to its nominal temperature.

5.4 Computers

Each water vapour monitor has an industrial PC, which has three tasks (Fig. 5.10):

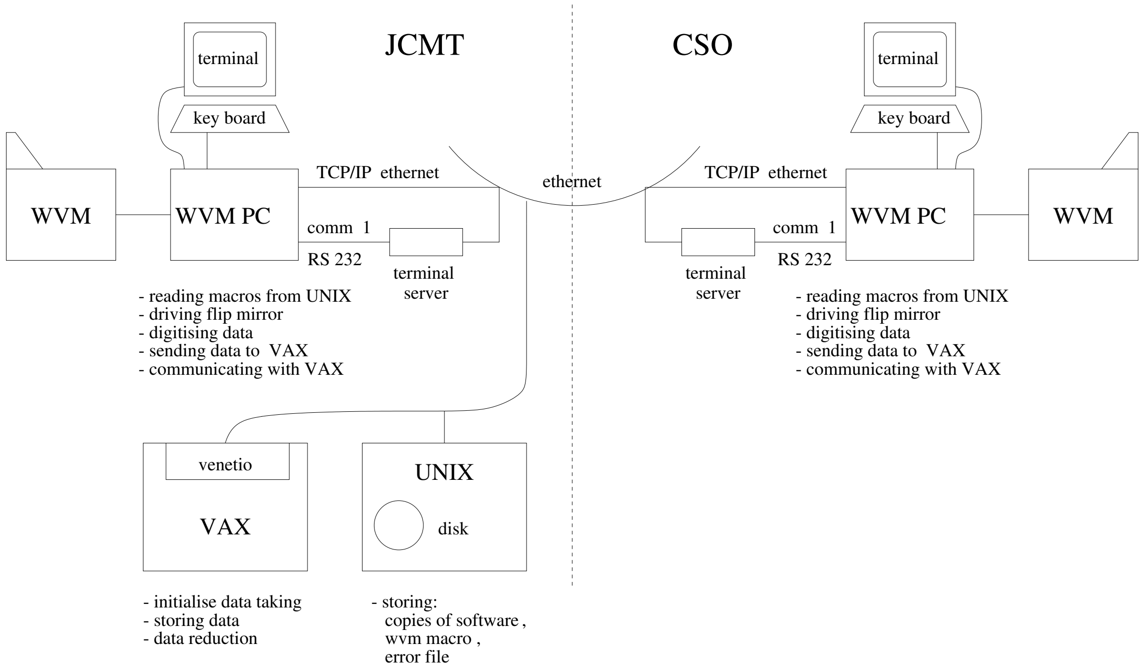

Figure 5.10. Schematic of the computers involved in running the WVMs. The PC drives the flip mirror and digitises the data. Since the memory and computing power (CPU) of the PC are fairly small the data is stored and reduced on the VAX at the JCMT. The VAX is also used to start and synchronise the data-taking of both WVMs. The macro which defines the calibration cycle is stored on the UNIX, where both PCs can access it.

1. The PC sends a logical signal to the motor control which rotates the flip mirror to different positions, so that the water vapour monitor can observe either the sky or one of the calibration loads (see §4.4).

2. Secondly, the PC digitises the signals from the water vapour monitors. The four V/F converters of the WVM send four frequencies representing the detector output of the three IF channels and a temperature measurement of one of the temperature sensors to a counter board in the PC. The frequencies are counted, digitised and stored. As the flip mirror moves, the detectors for the three IF channels will measure emission from the hot load, the warm load and twice from the sky. At the same time the fourth V/F will convert the temperature measurements of the sensor in the hot load, in the warm load, on the IF plate and on the RF plate. Therefore for each calibration cycle an array of 4×4 numbers is obtained.

3. Thirdly, the WVM PC needs to communicate with the VAX and the UNIX computer at the JCMT. The PC is connected to the Ethernet directly as well as via an RS232 link and a terminal server.

The macro which defines the calibration cycle is stored on the UNIX computer at the JCMT. The length of the calibration cycle can be changed easily on this computer. Both PCs are connected to the UNIX computer via the RS232 link, so that they will drive the mirror control with the same macro. In case the connection can't be established, each PC has a backup version of the macro stored in its own memory chips.

The VAX computer at the JCMT is connected to both WVMs via the Ethernet. Data-taking programs are run from the VAX. First a connection from the VAX to both PCs is established and they are synchronised. Thereafter every second the VAX reads the data array of 16 numbers from each PC. These 16 frequencies and the time are stored in a binary file, which is later used in data reduction (see chapter 6).

5.5 Performance of electronics

5.5.1 System temperature

The input power of the LO can be adjusted to give the best performance of the mixer. However, the optimum LO power is different for different IF frequencies. The LO power was adjusted to give a compromise between all channels. The current set-up has system temperatures between 2000 and 3000 K. As discussed above the thermal noise in a one second integration time from these system temperatures is just lower than the accuracy required.

5.5.2 Frequency stability of LO

The PLL keeps the Gunn at 91.665 GHz with an accuracy much better than 20 kHz. Fig. 5.11 is a sketch of the locked LO when monitored with a spectrum analyser. The width of the peak is determined by the resolution of the spectrum analyser. Since the peak did not move on the screen of the spectrum analyser the stability of the PLL must be much better than 20 kHz. Within the loop band width the phase noise comes from the 145 MHz crystal oscillator, outside it is determined by the Gunn. The "shoulders" indicate where the transition takes place.

Since the Gunn is locked with respect to the DRO and the crystal oscillator any shift in their frequency will also shift the LO frequency. Between 0 and 70 C the DRO has an accuracy of 10^{-5}, i.e. 102 kHz. This could result in a phase shift of 9×102 kHz in the LO frequency. The crystal oscillator also has an accuracy of $\sim 10^{-5}$, i.e. 1.45 kHz, resulting in a shift in LO frequency of only 1.45 kHz. The total accuracy in the LO frequency is therefore better than 1 MHz.

A change in LO frequency will also change the filter frequencies, but to first approximation the detected power will be independent of the LO frequency, see Fig. 5.12. Consider measuring the signal in a narrow frequency band located e.g. 1 GHz above and below twice the LO frequency. If the LO moves up in frequency, the signal in the lower frequency band will rise as it gets closer to the centre of the water line, but the signal in the upper band will decrease, see Fig. 5.12. If the water line can be approximated by a straight line over the width of the filter, the measured signal, which is the sum of these two signals, will stay constant.

For the correct line shape a LO frequency shift of 100 MHz will change the measured signal of a channel 0.8 to 1.8 GHz away from the line centre by 3.3×10^{-5}, i.e. by 0.007 K in

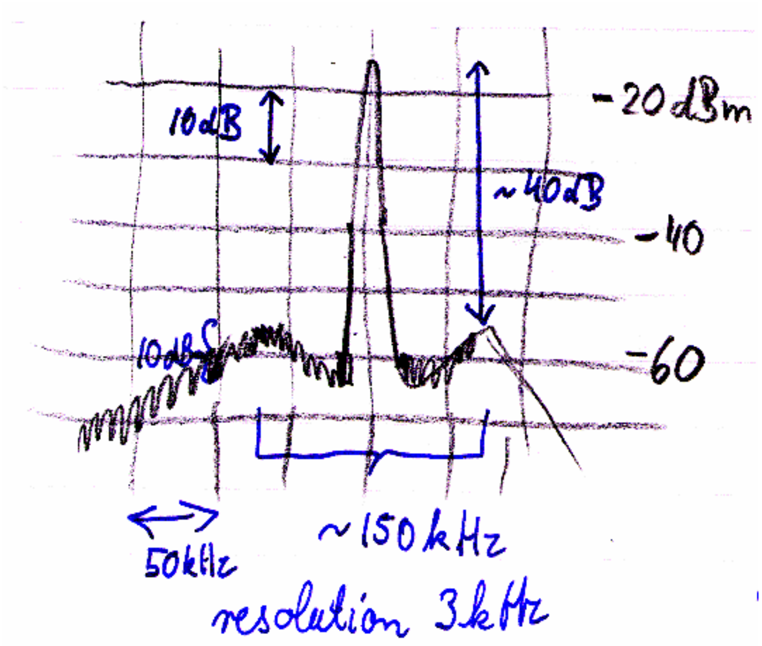

Figure 5.11. Sketch of locked LO taken from the notebook. The strength of the oscillator is plotted against frequency. Ideally, the LO should only oscillate at one frequency and the plot should show a delta function. The sketch shows a strong peak of the LO; Its width of 20 kHz is due to the limited resolution of the spectrum analyser. There is also some power at other frequencies. The loop bandwidth is $\sim$ 75 kHz, half the width of the "shoulders". Inside the loop bandwidth the 145 MHz oscillator, to which the LO is locked, determines signal stability and the phase noise. Outside the the loop bandwidth the phase noise is due to the LO.

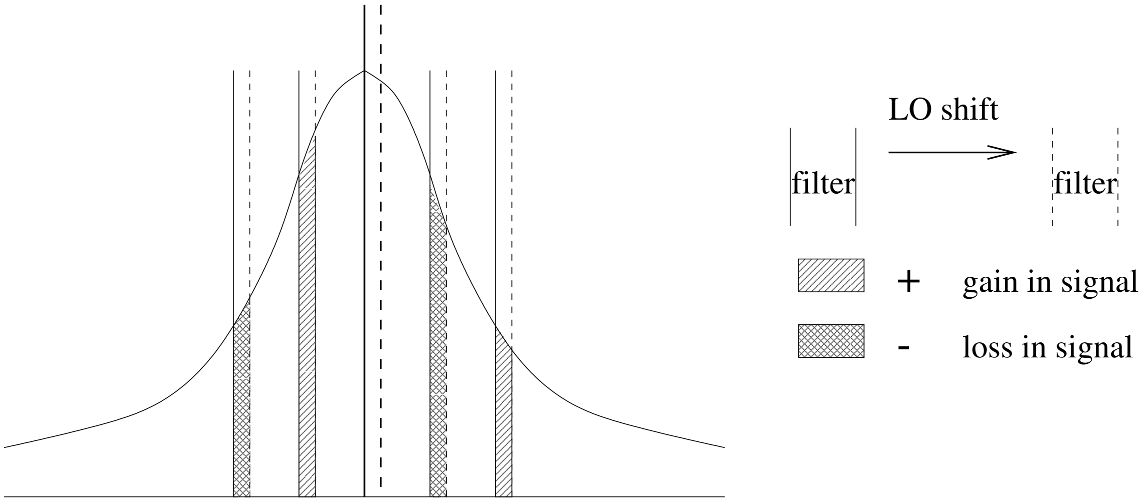

Figure 5.12. Effect of shift in LO frequency on detected power of water vapour line. If the LO frequency shifts to a higher frequency both filters shift up as well. There will be more power in the left filter, but less in the right filter. To first approximation the sum of the detected power in both filters will be constant.

$\sim$200 K. This change is very small and not significant.

In summary, the expected shift of LO frequency of 1 MHz will not change the detected power significantly. The error is so small that it can be neglected.

5.5.3 Frequency response

Ideally all amplifiers used should have a flat gain curve, i. e. their amplification should be independent of input frequency. Similarly the mixers should have a constant conversion factor and the detector should be equally sensitive to signals at different frequencies. To measure the combined response of IF electronics of the WVM a signal of constant power but at varying frequency was used as an input into the IF circuit (Fig. 5.6). In Fig. 5.13 detected power is plotted versus frequency for channel II. The response is not perfectly flat. No power is detected at 4.2 GHz the frequency of the crystal oscillator because after the second down conversion 4.2 GHz becomes $\sim$ 0 GHz which cannot be detected, because there is a capacitor at the detector input. According to the discussion about down conversion in §5.2.2 the passband of filters and the gain of amplifiers applied after the second down conversion is not

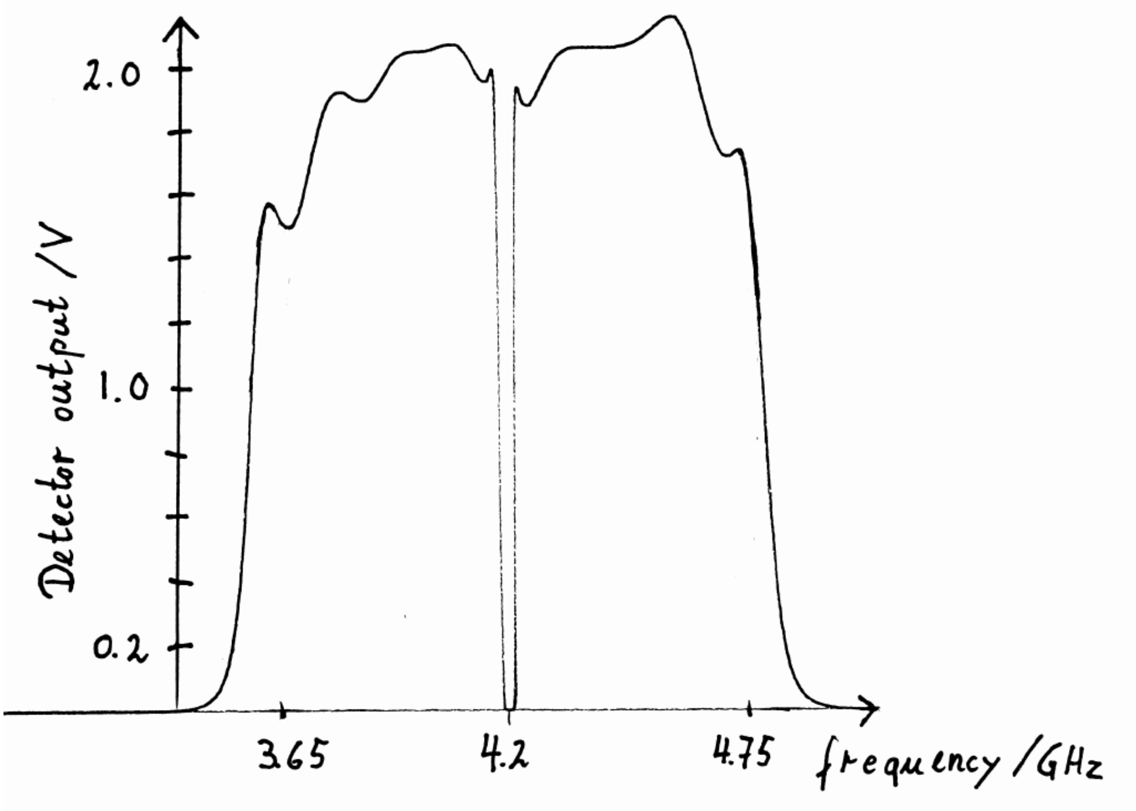

Figure 5.13. Plot of detected power versus input frequency. A signal of constant power but with a frequency varying between 3.4 and 4.9 GHz was used as an input to the IF channel (Fig. 5.6). The signal was amplified, mixed with the 4.2 GHz crystal oscillator signal, further amplified and detected. The plot gives an indication of the gain of the amplifiers,passband of the filter and response of the detector.

of importance. Any amplification and filtering applied after the second down conversion will be symmetric about 4.2 GHz in Fig. 5.13. Therefore only any asymmetry will contribute to an error.

To estimate an upper limit for the error in deduced brightness temperature we assumed that the response between 3.5 and 4.2 GHz is 10% lower than the response between 4.2 and 4.9 GHz, this results in an error of 0.5 K. The difference in response is expected to be nearly constant and vary by less than 10% or 0.05 K over one hour. When measuring the brightness temperature fluctuations we take differences therefore only the 0.05 K error will contribute. This error is much smaller than the accuracy of 0.5 K we are aiming for.

5.5.4 Gain fluctuations

Given an input signal at constant power the output voltage will fluctuate slightly due to changes in the overall amplification and attenuation of the input signal. The gain of the amplifiers is especially sensitive to temperature changes of the amplifier itself. Therefore all electronic components are mounted on temperature regulated plates. The gain fluctuations at the JCMT WVM are very small with a root mean square variation of 0.1 K comparable to thermal noise in a 3 second integration, see Fig. 5.14. The CSO WVM shows bigger gain variations of about 0.4 K rms over about a 6 minutes period. This is probably due to the CSO WVM being mounted outside and therefore being much more exposed to the weather. Every second the water vapour monitors are calibrated against loads at constant temperature, so that the amplification and therefore the gain variation of the system is known and can be taken into account during data analysis.

5.5.5 Temperature stability of plates

The temperature stability of the plates, on which all the electronics are mounted, is very high with an rms fluctuation of 4 mK. This ensures a constant temperature of the electronics and therefore reduces the gain variations.

5.5.6 Spikes in data

Most of the spikes have been eliminated by only using the good counters in the counter board and by sending a very clean signal from the voltage to frequency converters to the counter

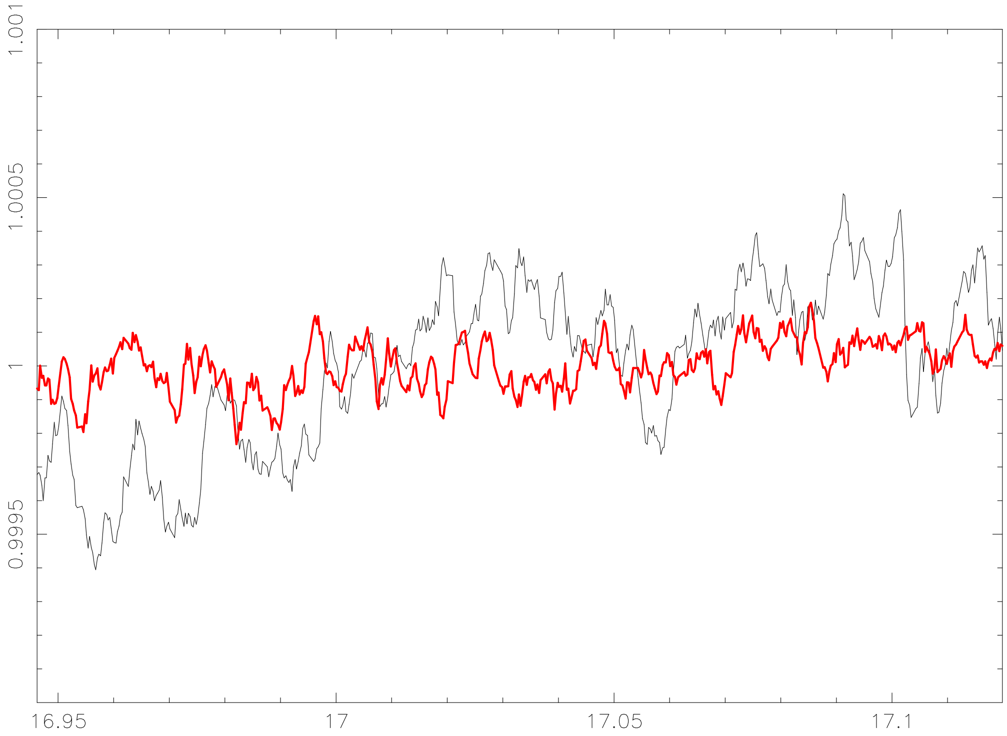

Figure 5.14. Gain variations. The thick (red) line shows the gain variations of the JCMT WVM against time in hours and the thin line the gain variations of the CSO WVM. The data were hanning smoothed over 10 s. Full scale of the y-axis corresponds to about 5 K.

board in the computer. Unfortunately, however, there are still some spikes in the data.

There seem to be at least two different types of spikes: The CSO data shows spikes in channel II and III, but only when integrating on the sky and not during observations of the loads. The spikes always occur at the same time in both channels, but at irregular intervals of 40 to 100 sec. The JCMT WVM has much fewer spikes, which occur in all channels. (See also §6.3.2 under spikes.)

The origins of these very sudden changes in detected power are unknown. Possible explanations are:

- Crosstalk of frequency outputs:
  All the frequency outputs of each WVM are sent to the data taking PC along one cable. Interference between the different frequency signals in this cable could cause spikes.

- Interference by astronomical receivers:
  Since the spikes in the CSO WVM only occur in the sky channel this might indicate that these spikes are caused by a signal from the telescope such as an interfering signal from the astronomical receivers.

- PC:
  Since the PC has very limited computing power, it might miscount the frequencies, when it is interrupted, for example, by the VAX sending commands.

It is desirable to eliminate the origins of the spikes as far as possible. Large spikes, however, won't degenerate the quality of the data very much as they are easily removed during the data reduction.

5.5.7 Summary

The water vapour monitors could still be improved slightly by reducing the gain variations of the CSO WVM and by eliminating the origin of the spikes. Overall, however, the electronics of the water vapour monitor performs very well and the radiometers fulfill the requirements for phase correction.