ALMA Newsletter

September 2010

ALMA

Introduction

Dear ALMA newsletter recipients,

As this editorial is written, we have seven antennas at the Chajnantor plateau, the “High Site”. Seven antennas means twenty-one baselines, i.e. more than twice as many as we had only two months ago. As you know, the bonus we have in interferometry is that the the number of baselines increases roughly with the square of the available antennas. The image quality can be further enhanced, because the projection of a celestial source onto the existing baselines changes due to the rotation of the Earth.

A large number of baselines is important but not sufficient to fulfill one important promise of ALMA, namely to provide crisp images. Unlike the sharp images from the Hubble Space Telescope, images from ground based optical or radio telescopes are blurred by the Earth’s atmosphere. It is the Holy Grail of observing astronomy to overcome such atmospheric effects. Recently, ALMA has made a big step toward this goal by using Water Vapor Radiometers operating at 183 GHz to measure the amount of atmospheric water vapor at any instant in the line of sight of each antenna, and applying a corresponding correction to the astronomical data received. This not only improves the image quality, it is essential for using ALMA at its lowest wavelengths of around 0.3mm and at baselines exceeding several kilometers. Achieving this has a been a collaborative effort involving many parts of project and there are all to be congratulated.

JAO has now moved into our new Santiago Central Office in Vitacura next to the ESO premises, ending a phase of two years were Santiago based staff was distributed in two different buildings. This new ALMA office will also host the ALMA archive. Although ALMA users are normally not expected to come to Chile to observe, there will be office space for visitors, since ALMA has been and will always be a cooperation of people from many countries and many fields of science and engineering.

This newsletter contains a list of workshops, schools and conferences dealing with ALMA, reflecting the interest of the astronomical community in our project. I invite everybody to join these events in order to discuss the exciting science made possible with ALMA, and to learn how to use this instrument in an efficient way. After all, the first call for ALMA observing proposals will be released very soon.

After having served as ALMA Project Engineer since 2004, Rick Murowinski has decided to go back to Canada. We thank him for his important contributions to our project during very crucial years and wish him all the best for his future career.

Enjoy ALMA’s universe!

Thijs de Graauw, ALMA Director

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

Credit: ALMA (ESO / NAOJ / NRAO)

Focus on...

Correcting for the Effects of the Atmosphere

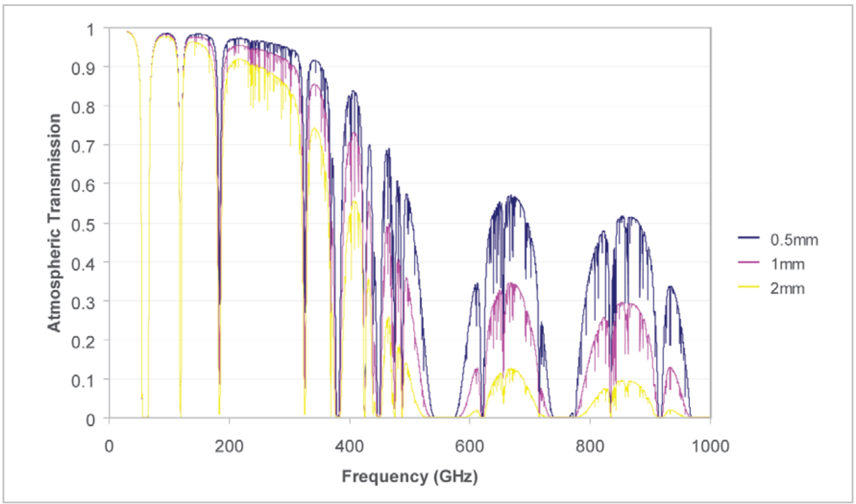


Figure 1. Atmospheric transmission for three different amounts of water vapour.

by Richard Hills, ALMA Project Scientist.

The reason that ALMA is located where it is – on a high mountain plateau in an extremely dry part of the world – is of course to minimize the effects of water vapour in the atmosphere. Water has a number of undesirable effects from the point of view of millimeter-wave astronomers. First of all, it absorbs the signals that we are trying to observe. This is illustrated in the well known plot of the transmission of the atmosphere as a function of frequency, shown in Figure 1.

Here the narrow absorption features are due to Ozone (which is another story) and a few of the other lines are due to Oxygen, but almost all the rest of the absorption – both the wide deep lines and the broad absorption covering all of the higher frequencies – is due to water vapour. This can be seen from the fact that the amount of absorption changes with the amount of water, as shown by the different colours. The amount of water in the atmosphere is here represented by a thickness – the values 0.5, 1 and 2 millimeters. This is simply the thickness of the layer of water that would be formed if all the water vapour in the atmosphere were to be precipitate out onto the ground. We call this the “precipitable water vapour”. On a typical sea-level location this quantity would be 10 or 20 mm and essentially no sub-millimeter signals from space would reach the ground at all. The values on the ALMA site are typically in the range shown in the plot and it is sometimes even drier. Last month we recorded values as low 0.12 mm!

ALMA Newsletter

September 2010

Credit: ALMA (ESO / NAOJ / NRAO), William Garnier (NRAO).

Focus on...

Figure 2: An ALMA antenna showing the main reflector, subreflector and central hole.

Since the amount of water is varying all the time, and since this changes the amount of attenuation that is suffered by the signals that we are observing with ALMA, it is clear that we need to be able to measure the amount of water that the telescopes are looking through, so that we can correct for this attenuation. We do this by using instrument called a "water vapour radiometer". This is mounted in the receiver cabin and looks up at the sky in the direction where the signals are coming from. Figure 2 is a reminder of how the ALMA antennas collect the millimeter-wave signals. The signals fall first on the main reflector, which focuses them on the small subreflector supported by the four "legs", and this reflects them through the hole in the center of the main reflector and into the receiver cabin behind.

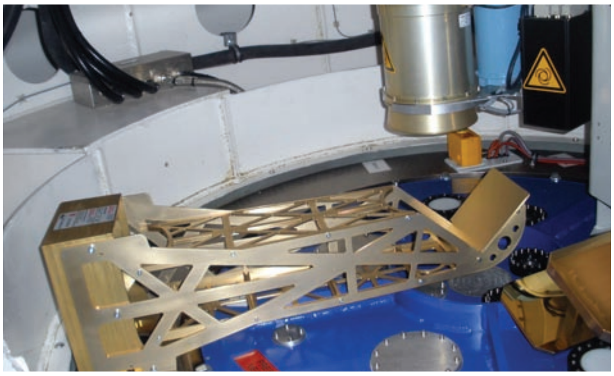


Figure 3. The Optical Relay which takes the signal to the Water Vapour Radiometer.

Inside the cabin the signals come to a focus and can pass into one of the "windows" in the top of the (blue) cryostat containing the exquisitely sensitive receivers used to detect the astronomical signals. There is, however, an additional item in the receiver cabin called the "optical relay", which picks of the signals that arrive right in the middle of the focal plane and takes them off to one side. Figure 3 shows this arrangement.

The radiometer itself is mounted to one side of the cryostat, and from the outside appears as a rather undistinguished box seen in Figure 4.

Once they are installed, it is not possible to see both the relay and the radiometer at the same time, but the overall scheme can be seen in Figure 5.

Figure 4. A water vapour radiometer installed in the receiver cabin.

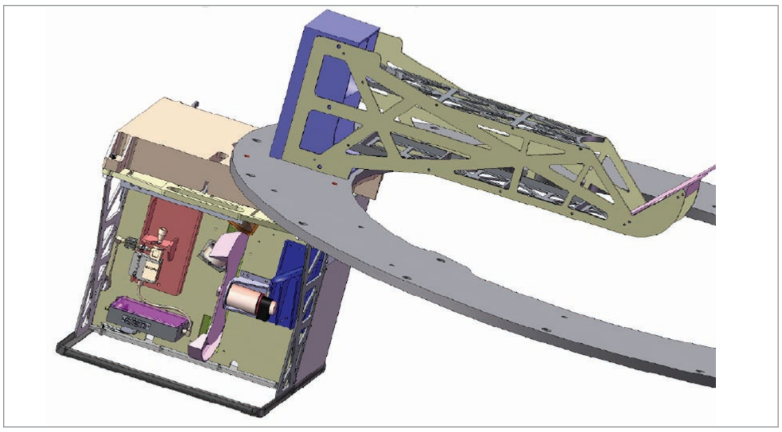


Figure 5. Drawing of the Relay and Radiometer. (Courtesy of Omnisys Instruments AB)

Credit: ALMA (ESO / NAOJ / NRAO), William Garnier (NRAO).

Focus on...

Figure 5 also gives an impression of what is inside the radiometer, and this is shown in more detail in Figure 6.

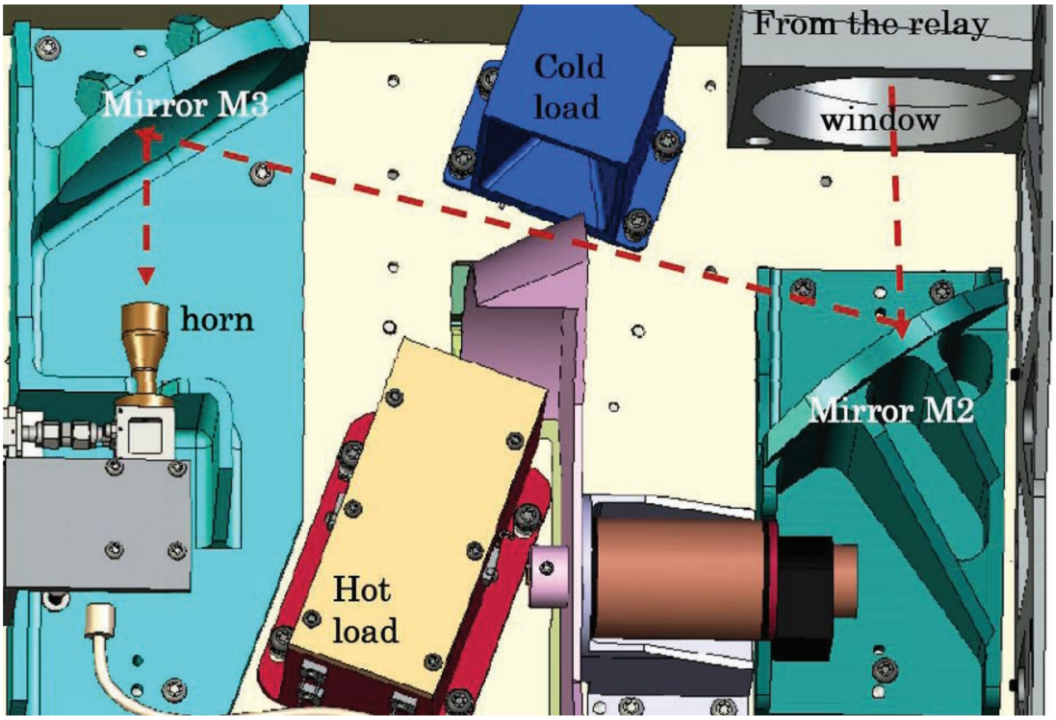


Figure 6. The optical sections of the radiometer (Courtesy of Omnisys Instruments AB).

The radiometer is actually another millimeter-wave receiver, but a very specialized one. The point is that in addition to causing absorption, the water vapour in the atmosphere also emits millimeter wave signals. In fact, there is a fundamental law of physics that anything that acts as an absorber will also act as an emitter, with the amount of emission being proportional to the amount of absorption multiplied by a function of the temperature of the material. In general, this emission from the water in the atmosphere is another nuisance for the astronomers in that it adds to the noise in the observations. Here, however, we can turn it to our advantage and use the emission to measure the amount of water. The radiometer is designed to detect the emission at around 183 GHz where there is a strong emission line of water. This is one of the features that can be seen in Figure 1.

The radiometer includes a chopper wheel (purple object in the centre of Figure 6), which spins rapidly and is shaped so that the signals arriving at the "horn" on the detector (on the left in Figure 6) come first from the cold load, then from the sky (through the relay and the reflectors of the antenna), then from the hot load, and then again from the sky. Since the temperatures of the hot and cold loads are accurately controlled, the signals from them can be compared to those from the sky making a very accurate measurement of the amount of emission from the sky possible.

Credit: ALMA (ESO / NAOJ / NRAO), William Garnier (NRAO).

Focus on...

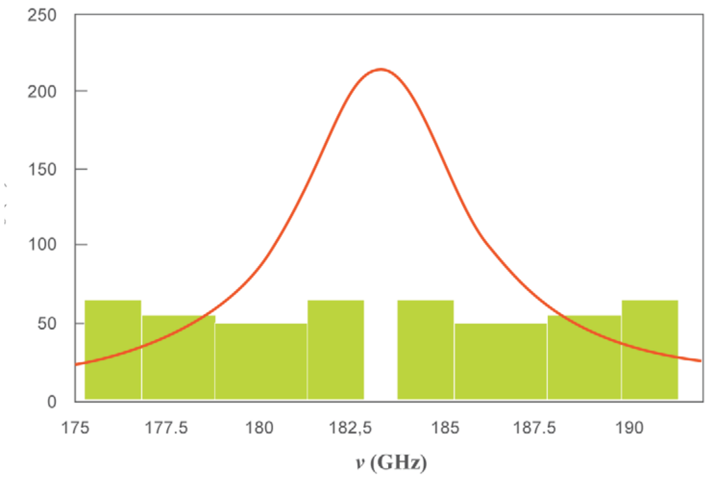


Figure 7. Close up of the 183 GHz emission line of water vapour and the frequency coverage of the channels of the radiometer. (Credit Bojan Nikolic.)

After the signals enter the horn they are down-converted to lower frequencies and divided into four channels on either side of the emission line. This is illustrated in Figure 7.

By combining the readings of these four channels it is possible to make an accurate estimate of the amount of water along the whole path though the atmosphere through which the astronomical signals have passed. As already explained, we need to know this in order to correct for the attenuation which the signals have suffered.

The reason that we have taken so much trouble over the design and construction of the radiometers is, however, to correct for a further effect of water, which is in some ways even more critical for ALMA than the attenuation. As well as producing absorption and emission, the water vapour also acts as a dielectric, which means that it slows down the propagation of the signals. Another way of saying this, is that it is as if the signals have had to propagate over a slightly longer path, so they arrive a little later than they would if there were no water at all in the atmosphere. Roughly speaking 1 mm of precipitable water vapour causes 6 mm of additional path. Figure 8 shows the estimated values of this excess path deduced from the readings of the radiometer on three of the ALMA antennas over a period of about half an hour.

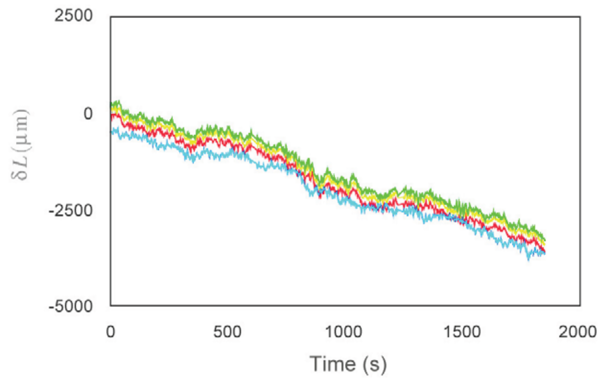


Figure 8. Additional path due to water vapour from three different antennas. (Credit Bojan Nikolic.)

It can be in our example here that the excess path has been falling slowly with time and the reason for this is that the object being observed was rising so the amount of water that the signals had to pass through was falling.

So long as the water is distributed very evenly in the atmosphere, as it was when the data shown in figure 8 were taken, then this has little effect on the astronomical observations. Much of the time, however, the water distribution is not at all uniform because turbulence mixes air from different levels in the atmosphere where the amount of water is different. Figure 9 shows what happens in this case: the excess path varies as the wet and dry air passes through the beam and of course the effect is different for the different antennas.

The fact that the paths to the antennas differ and that these differences vary with time causes a serious problem for ALMA, since is means that coherence between the astronomical signals would be at least partially lost if nothing were done about it. In particular the variation in the paths causes errors in the phase difference that is observed between each pair of antennas. These errors would then distort the images formed from the signals. This effect is of course very similar to the "seeing" effect of the atmosphere, which distorts the images formed by

Credit: ALMA (ESO / NAOJ / NRAO), William Garnier (NRAO).

Focus on...

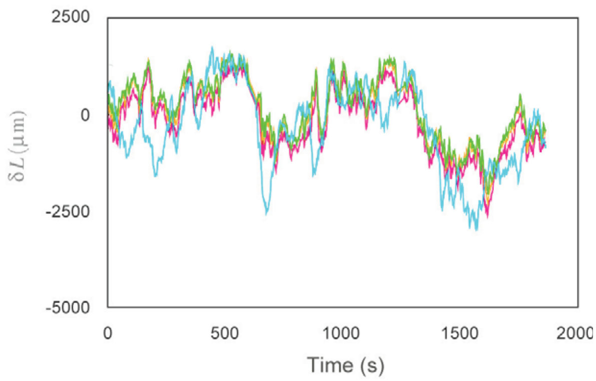


Figure 9. As figure 8 but under less stable conditions. (Credit Bojan Nikolic.)

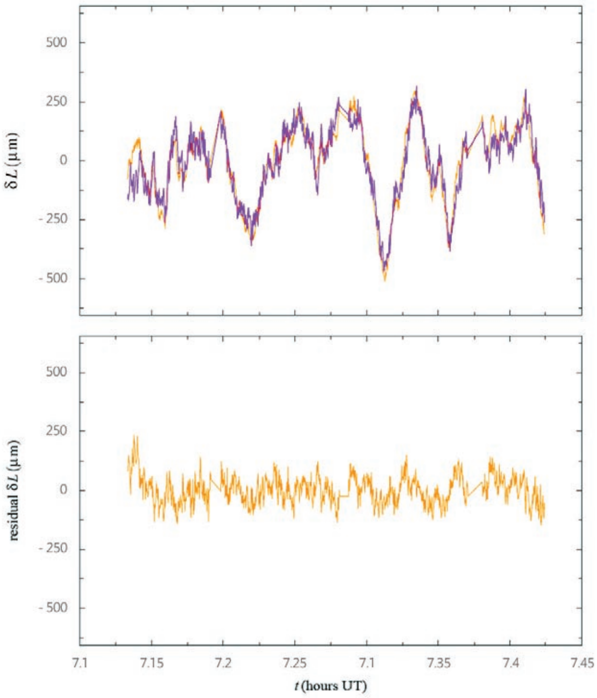


Figure 10. Phase Correction on a mm source. In the upper plot the red line is the raw phase of the astronomical signals (converted into a path difference), and the blue line is the difference as measured by the radiometer, while the lower plot is the residual after applying the correction. (Credit Bojan Nikolic)

optical telescopes, although the main cause of optical seeing is the fluctuations in the temperature of the air instead of the fluctuations in the amount of water vapour. In the case of ALMA we can use the estimates of the excess path made from the radiometer data to correct for the path fluctuations. This is illustrated in Figure 10.

The effect of the path fluctuations on the images depends on the observing wavelength: when the peak-to-peak variations are comparable to the wavelength the images become almost completely washed out. So in conditions like those when the data shown in Figure 10 were taken observing at wavelengths shorter than about one millimetre would be virtually useless without phase-correction, whereas with correction it should still be possible to obtain good, sharp images down to the shortest wavelength for which ALMA is designed, which is about a third of a millimetre.

The use of this method of correcting for the atmospheric fluctuations is one of the things that are being testing during the commissioning phase of ALMA. As indicated above, what we are finding is that there are times when the atmosphere is rather stable and no correction is needed, and that there are times when there are strong fluctuations and the correction can be applied and works rather well. There are unfortunately also occasions, and in general this is when there are clouds present, where there are strong phase fluctuations but using the data from the radiometer in the relatively simple way illustrated here does not help very much. This is probably because the emission from the water droplets in the clouds is invalidating the readings from the radiometer, but we plan to investigate this further and see how much correction can in fact be achieved under these conditions.

The radiometers were designed and are being built by Omnisys Instruments AB, Gothenburg, Sweden. They make use of concepts developed in a prototyping phase carried out jointly by the Cavendish Astrophysics Group in Cambridge, England and Onsala Space Observatory, Sweden. The water vapour radiometers are an ESO deliverable and the program is being managed by European Front End IPT. The enhanced analysis algorithms are being developed at the Cavendish Astrophysics Group under a contract from ESO supported by the FP-6 program of the European Union.

ALMA Newsletter
September 2010

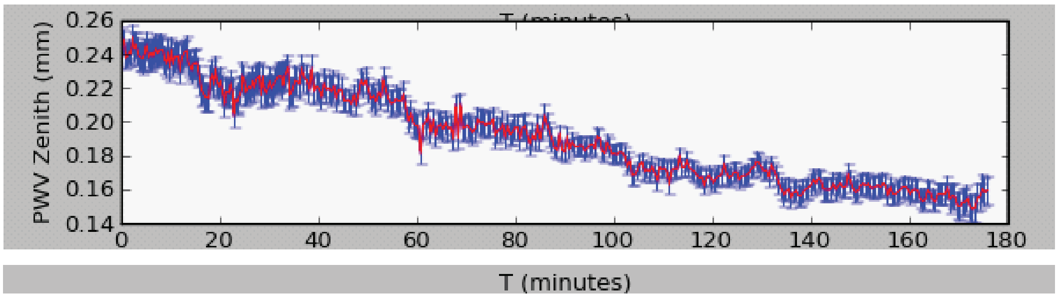
Credit: ALMA (ESO/NAOJ/NRAO)

Progress at the ALMA site

Here is a short synopsis regarding the recent progress of the site construction work:

Antennas

After the move of an antenna from the 2900m altitude Operations Support Facility (OSF) to the 5000m altitude Array Operations Site (AOS) on 6 September, we have now 7 antennas at the Chajnantor plateau. These will be joined by an eighth at the beginning of October. The twenty-eight baselines available between these eight antennas will definitely offer a marked improvement in ALMA's imaging ability. With five antennas, the array provided ten baselines; imaging excellence increases approximately as the square of antenna number.

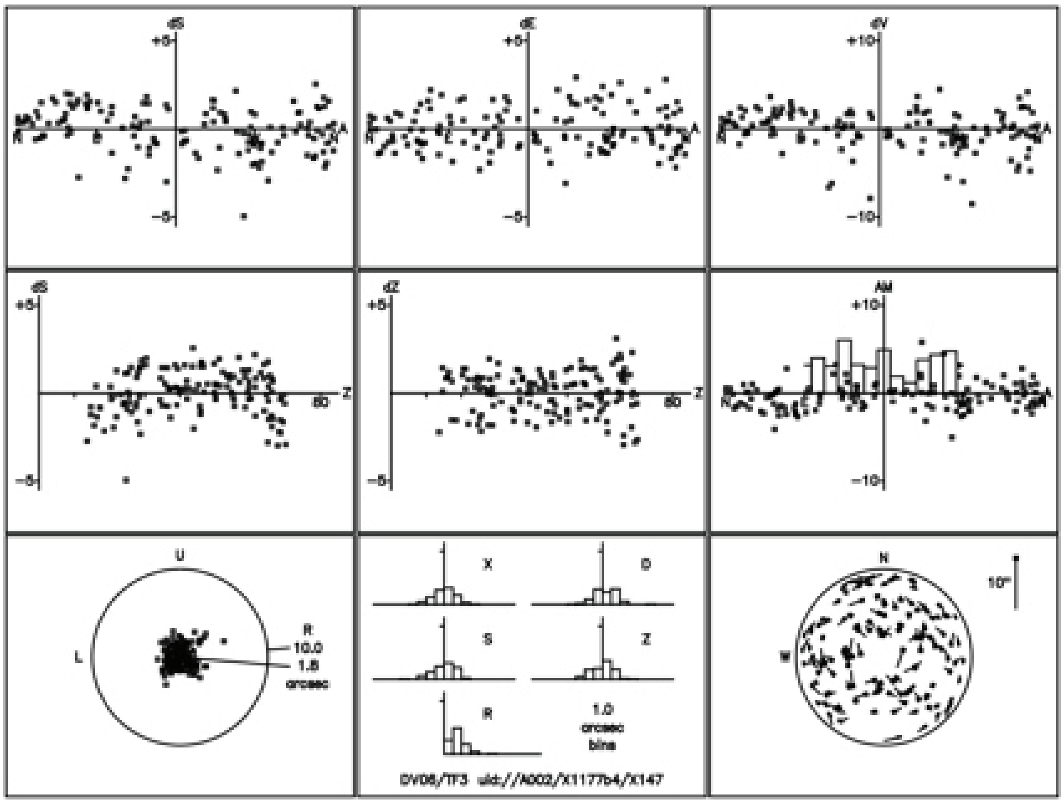


Over the last couple of months, most of the available time was taken up with technical tests of the antennas and other systems and demonstration of new features. There were spectacularly good conditions at the end of June, as illustrated in this plot of precipitable water vapour for the evening of 30 June (It actually carried on down to 0.12mm!). While essentially all of the ALMA hardware is in place, the software that enables its use is deployed in incrementally, at six-month intervals. Hardware functionality can only be fully tested according to the ability of the software releases to accommodate the tests. A new software release containing many new capabilities was released in June and installed on the array. A particular focus now is, of course, the testing of capabilities that are scheduled for availability during ALMA Early Science, expected next year.

ALMA Newsletter
September 2010

Progress at the ALMA site

Antennas are moved to the AOS after being conditionally accepted at the contractor's site and moved to the OSF. Each antenna is outfitted with electronics and put through exhaustive tests at the OSF by the Assembly, Integration and Verification (AIV) team. So far, twelve antennas have been conditionally accepted by the Project and have entered into this process. After outfitting and initial tests, the antennas at the OSF are normally combined into a two- element interferometer for final tests, performed to improve the capabilities of the instrument. For example, we find that we can do pointing measurements much more accurately with the interferometer than with a single antenna working alone.



Here is the analysis (made with the TPOINT™ package from Patrick Wallace) of such an interferometric pointing run demonstrating conformance with the ALMA requirement of 2 arc second rms accuracy over the whole sky.

Progress at the ALMA site

This two-element interferometer also provides a staging platform for new software, as was done for the recent release. At the moment, three antennas are undergoing testing at the OSF and interferometry there will undergo a short hiatus as tested antennas move to the AOS. In the mean time, many other antennas are being assembled and tested at the antennas assembly sites.

At the East Asian site, two MELCO (Mitsubishi Electric Corporation) 12-meter diameter antennas are now close to meet ALMA stringent technical specifications and thus begin the acceptance review process. A 7-meter diameter antenna is submitted to an holography campaign, a process in which the antenna observes the signals from a special transmitter located on a nearby tower. The surface measurement of this 7-m antenna has demonstrated very good performance, the best test conducted so far having concluded to an accuracy less than 6 micrometers rms. Four 7-meter diameter antennas have been shipped to Chile and might join their peers in a couple of weeks.

The North American assembly site is receiving its sixteenth antenna this month. Being nine of these antennas already conditionally accepted by ALMA, the work performed by the Vertex and NRAO teams is mostly focused on the other seven antennas currently on site. These are in different stages of construction and are submitted to the more than 200 tests that will eventually lead to the acceptance by the Project and their move to their new home at the OSF for further testing and integration, before being moved to their final location at the Chajnantor plateau.

Significant progress has been achieved at the European Antennas assembly site as well, where one antenna is ongoing acceptance testing while five others are in different stages of assembly.

Among these five, two are under final commissioning, one is in final assembly stage (commissioning phase should start in a few weeks), one is waiting for the Reflector to be installed at the end of the month and the last one is just starting its site assembly phase.

One of the major achievements was the relocation on June 23rd of the two first AEM antennas in one day using the ALMA transporter. This was the first time that AEM antennas had been lifted with the transporter, the whole process was fully successful.

Progress at the ALMA site

Operations Support Facility

Construction of the ALMA Camp dorm expansion continued these last months. 24 of the 40 new dorm rooms were completed in August and are being occupied. The remaining 16 rooms will be completed during September.

Site Power

The kick-off meeting for the Multi-Fuel Power Generation System contract was held in early June. Completion of this final major piece of the permanent power system is scheduled for August 2011. Twenty-three kV power system work continues on schedule for trenching and installation of the power and signal transmission line between the AOS and OSF, and on civil works for the permanent power substations at the AOS and OSF.

Santiago Central Office

JAO moved to the new Santiago Central Office on 23 August. The new building is in Vitacura (Santiago) next to the ESO building. The new mail address of JAO is Av. Alonso de Córdova 3107, Vitacura, Santiago, Chile. All the phone numbers remain unchanged.

ALMA Newsletter

September 2010

Credit: ALMA (ESO/NAOJ/NRAO), Norikazu Mizuno (NAOJ)

ALMA In-depth

Sense and sensitivity - how ALMA's receivers work

by **Tom Wilson**, Head of the Radio, Infrared and Optical Sensors Branch at the U.S. Naval Research Laboratory in Washington, D.C., **Rainer Mauersberger**, ALMA scientist and **Antonio Hales**, ALMA Scientist

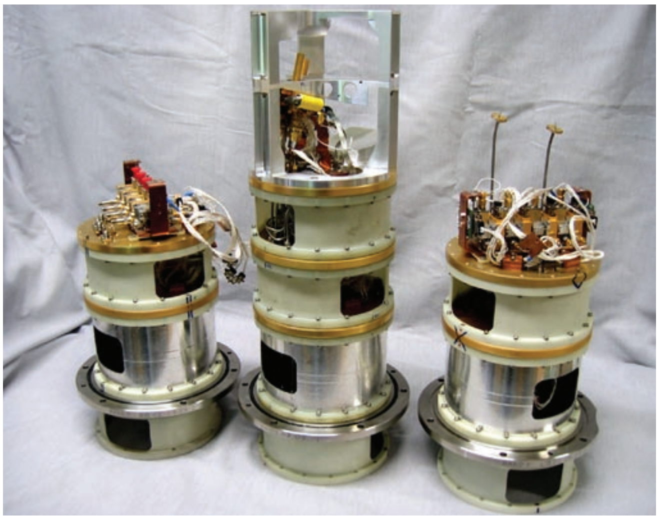


Fig.1 A photo of three Band 7 prototype front ends in various stages of construction. These are superconducting mixers (SIS) that efficiently convert the power at the sky frequency to a much lower intermediate frequency (IF) where the power is amplified greatly. The advantage of the SIS mixers is that these have contribute an extremely low noise, give rise to only very small losses in the input power and require only a small amount of local oscillator power.

In previous articles, we described how electromagnetic waves emitted from objects in the sky are collected by the ALMA antennas (Anatomy of ALMA), and how they are combined in order to produce images. Before these images can be processed, they are picked up by the antennas and concentrated by the large main mirror and a smaller secondary mirror in the so called focal point of each antenna. In order to process the data they must be first converted to electromagnetic waves of a lower frequency and amplified. This is the role of the ALMA receivers. In principle they work like a normal FM receiver, but at much higher frequencies. Here we describe how they work and what makes them special.

The receiver systems used for ALMA are the most sensitive built so far. There will be up to 10 different receivers per antenna (also known as ALMA Receiver Bands 1 to 10), each of which is sensitive to a specific wavelength (or frequency). By offsetting the telescope and tilting the subreflector one can select which receiver shall be used. Each receiver is equipped with a feed horn, that funnels the energy that is coming from the sky via the antenna into the receiver with minimal losses. It is difficult to amplify and process the high frequency radiation collected by the ALMA antennas. This is why the concept of mixing is employed in a first stage. This is the same principle as in

ALMA In-depth

a commercial FM receiver: The incoming (sky) signals are combined with an artificial oscillator signal of similar frequency. This produces a beat signal with a frequency that is basically the difference between the sky and the oscillator signal, but still contains all the information received from the celestial source. For obvious reasons, this stage is called the mixer. All ALMA receivers produced so far use superconducting components, the so called SIS (superconductor-insulator-superconductor) diodes, as mixers. The performance of these mixers was presented in ALMA Newsletter #2.

Fig.2 A photo of the cryostat that houses the SIS mixers and amplifiers. The SIS mixers must be cooled to 4 degrees above absolute zero to function optimally. The amplifiers following the SIS mixers are not cooled to such a low temperature, but these are also extremely low noise systems.

Briefly, the Front Ends can be described in the following. There are three essential items that contribute to the superior sensitivity of ALMA. These are: (1) the high, dry site, (2) the large collecting area and (3) the receiver system. The ALMA project has devoted a great deal to maximize the sensitivity contribution from the first two items. These include the Chajnantor site and the collecting area provided by 66 antennas that allow operation to 1 Tera Hertz. In the optical and near infrared (near IR) wavelength range, the sensitivity of astronomical detector systems has improved by about a factor of 25 since the 1960's. The sensitivity of millimeter and sub-millimeter astronomical receivers has improved by at least this factor over the same time. In the last few years, receiver sensitivity has improved by another factor of 2 to 4, due to the ALMA development program.

The optical and near IR detectors convert the incident radiation to electrical current in an efficient way. The millimeter and sub-millimeter (mm/sub-mm) receivers must fulfill a number of additional requirements beyond those that apply to the optical and near infrared detectors, that is, the mm/sub-mm receivers must also preserve additional properties of the incident radiation. The most important of these additional properties is the relative arrival time of this radiation at each antenna, that is, the relative phase. In addition, the polarization properties must be accurately recorded. All of this must be done without corrupting the properties of the radiation, or adding more than a small amount of noise power. To accomplish this, the incident radiation is shifted to a longer wavelength (lower frequency) in the first element of the receiver (in a process called down-conversion). Then the power level of the radiation is increased by an enormous factor. Then this output is transferred to the Technical Building at the Array Operations Site (AOS), where the radiation is processed further to produce images.

The noise added by radio astronomy receivers is measured in temperature units, Kelvins. This is universally used as a measure of power for a unit bandwidth. Thus above 200 GHz in the

ALMA Newsletter
September 2010

Credit: ALMA (ESO / NAOJ / NRAO), Carlos Padilla.

ALMA In-depth

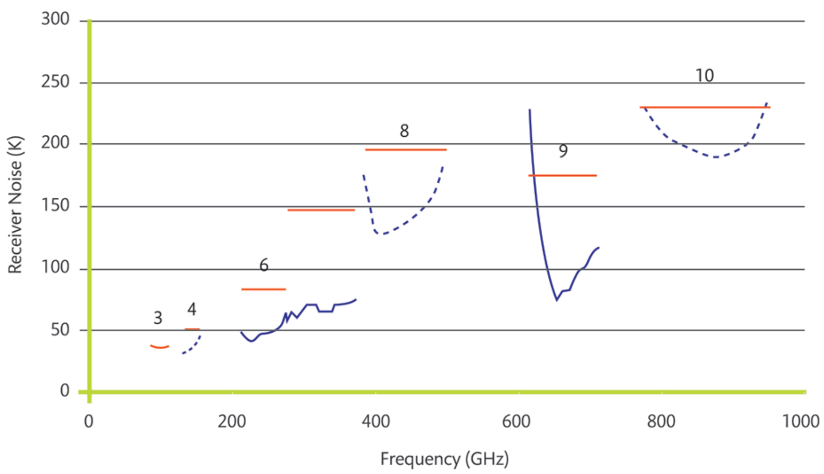


Fig. 3 Noise temperatures for the ALMA Receiver Bands, on the vertical axis plotted against receiver frequency, on the horizontal axis. The solid horizontal lines mark the specifications for ALMA receiver Bands 3, 4, 6, 7, 9 and 10 (Band 7 is not labeled). The dashed lines under Band 4, 8 and 10 indicate the present status which is in the development phase. The solid irregular lines under Bands 6, 7 and 9 show the present status of laboratory measurements of the receiver noise temperatures for these Bands. In wavelength these ALMA receivers cover a range from 3.5 millimeters to 0.3 millimeters. (adapted from a plot made by J. Webber, NRAO). Not shown on this plot are Receiver Band 5 (at about 180 GHz), which will be installed on six antennas, and Receiver Bands 1(about 30 GHz) and 2 (about 80 GHz), which will be built and installed at a later time.

plot of Fig. 3, the smooth horizontal line at about 70 K is the ALMA specification, while the uneven line starting at about 50 K is the actually measured receiver performance. It is interesting to compare the receiver noise with noise from the earth's atmosphere. The ideal situation is for a receiver mounted on a lossless antenna outside the earth's atmosphere. We can calculate the noise added to an earth-bound receiver to reach such an ideal. For an ALMA antenna on a very dry site at elevation 5 km, the earth's atmosphere would add 10 K to the noise of a Band 6 receiver. In this situation, the atmosphere adds about 20% to the measured noise of the Band 6 ALMA receiver. Thus, the sensitivity of millimeter receivers, such as Band 6, could still be improved somewhat, but for sub-millimeter receivers, such as Band 9, the earth's atmosphere adds a substantial amount of noise to the receiver contribution. Thus, ALMA receivers are close to ideal systems, especially in the sub-millimeter wavelength range where the earth's atmosphere contributes more noise.

It is worthwhile to present some of the principles needed to achieve the receiver noise temperatures of ALMA receivers. First, the receivers are superconducting devices, so-called Superconducting-Insulating-Superconducting (SIS) devices. The SIS is cooled to 4 Kelvin. The principle is that a flow of electrical current is hindered by the insulating layer. For a given receiver setting, the current will flow when the astronomical signal shines on the device. The SIS device has three useful properties: (1) converting radiation from the sky to electrical current, (2) by combining the frequency of the incoming astronomical signal with the one generated at the AOS building, converting the sky frequency to a much lower frequency (down-conversion), and (3) adding a minimum amount of noise to the astronomical signal. A specific example can be given for Band 7. The astronomical frequency could be, as an example, between 275 and 373 GHz (0.87 millimeters). If the astronomical signal of interest

ALMA In-depth

is at 345 GHz, this will be converted to 8 GHz (about 4 centimeters wavelength) with the signal properties such as amplitude, phase and sense of polarization preserved. The signal is then amplified. After amplification, the signal (plus a small amount of noise) is sent to the ALMA back end for transmission to the AOS building where it is combined with the outputs of the other ALMA antennas. Once combined, the outputs from 66 antennas are processed to produce an image.

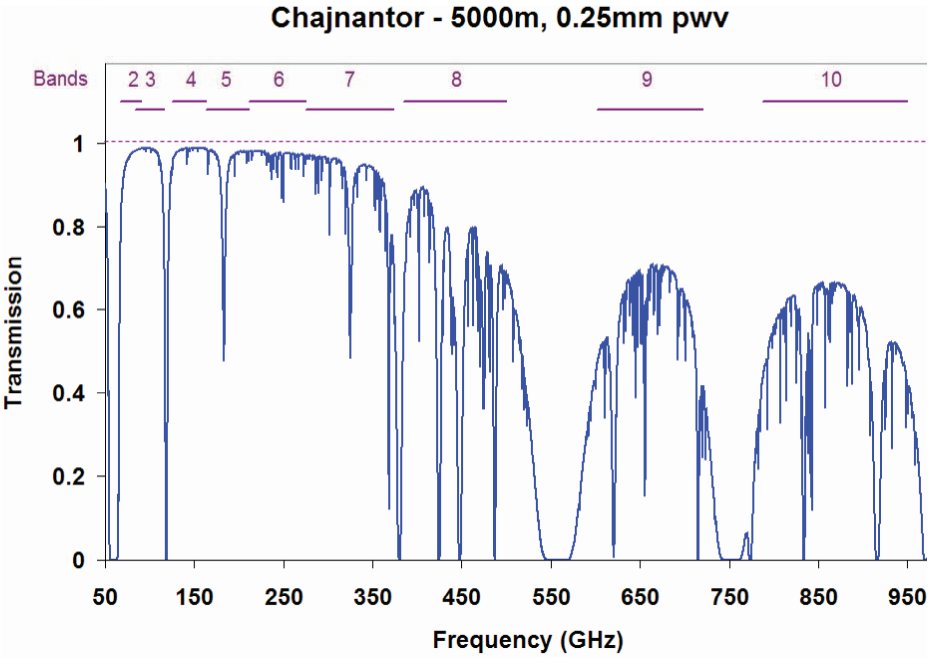


Fig. 4 On the left vertical axis is the transmission of the earth's atmosphere, on the right axis is the noise contributed by the earth's atmosphere. A transmission of 1 means that all the incoming light passes through the atmosphere without any attenuation. Zero percent transmission means that all the incoming radiation is absorbed by the atmosphere. This polt is for the ALMA site, at an elevation of 5 km. The total amount of precipitable water vapor (pwv) above the site can be as low as 0.25 mm This small amount ensures that the effect of the earth's atmosphere on system noise is a minimum.

Due to their nature, the SIS mixers contribute just a very small amount of electronic noise to the signal received, and give rise to only a small loss of the power entering the feed horn. As an example, if we are interested in a frequency range between 340 and 348 GHz in the sky, the astronomer or telescope operator first selects the corresponding band 7 receiver by offsetting the telescope and tilting the subreflector via the telescope control system. The power entering at 340 to 348 GHz is converted to a frequency of 4 to 12 GHz by the SIS mixer. The portion of sky frequencies to be measured is selected by the Local Oscillator (LO). This is an extremely stable, narrow band signal which is sent to all antennas. The power is subsequently increased by a vast amount, to 1 milli Watt, which is a power that can easily be processed.

Following the SIS mixer is another set of mixers that shift the single 4 to 12 GHz band into four bands, each from 2 to 4 GHz. This is done to allow identical electronics for the following stages. In each of those steps the information content of the signals (i.e. the relative frequencies, the relative intensities and, most important the phase, i.e. the timing of each wave) must be preserved. These 2 GHz wide bands, which are still analogue signals, are then digitized in the antennas. The digitized outputs are formatted to insure that no information is lost. These signals are now coded on top of signal of optical light, and transmitted on optic fibers, which are buried in the ground, to the Technical Building (TB) at the ALMA Operations Site (AOS) for further processing, needed to produce

ALMA In-depth

images. This process was alluded to in the description of "How ALMA will make images" in the last newsletter.

The preceding paragraph gives a correct, but not very informative description of how ALMA will function. A perhaps more enlightening version makes use of analogies. This is given in the following.

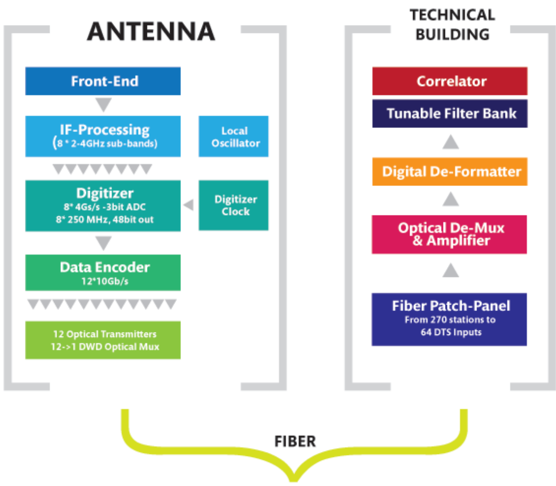
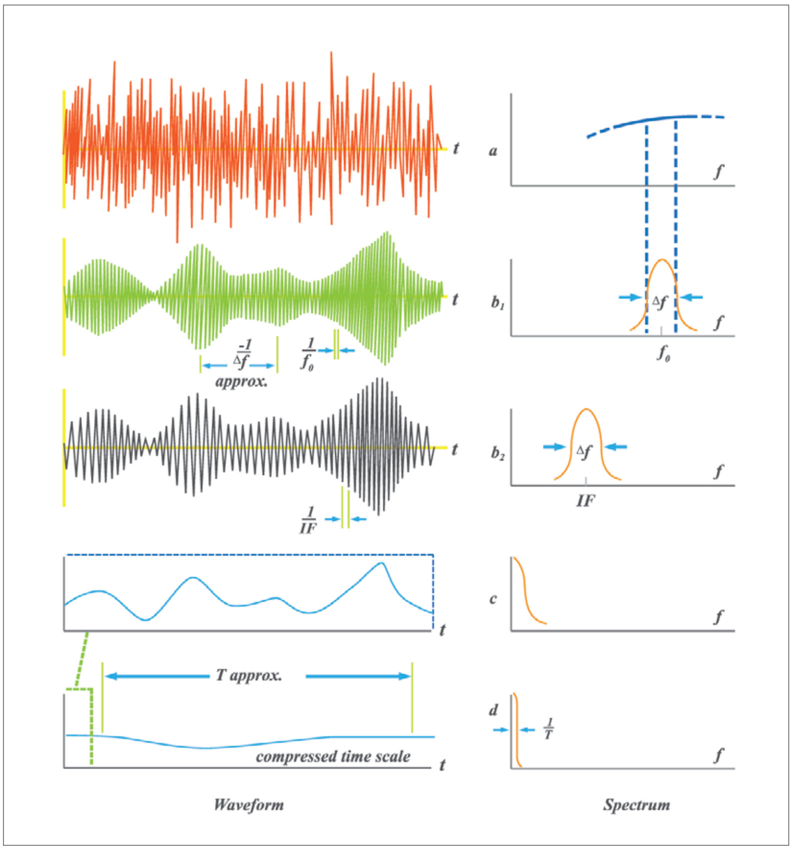


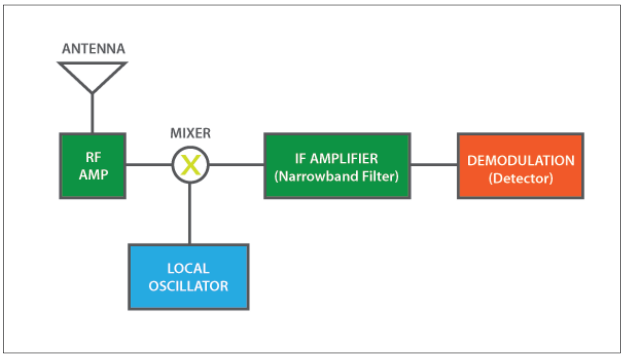
Fig. 5 A schematic of the ALMA back end design. ALMA electronics in the antenna (on the left) to the Technical Building (TB) at the ALMA Operations Site (AOS). The front end converts the input from the antenna to an IF frequency with four sub-bands of 2 GHz bandwidth for each of two polarizations. The output of each sub-band is digitized at a rate of 4 giga samples per second. This is then encoded, shifted to the optical and then transmitted to the AOS TB where the optical transmission is input to the 32 tunable filter banks (FB). The FB's are used to select specific bands of up to 2 GHz width within the 8 GHz band selected by the front end.

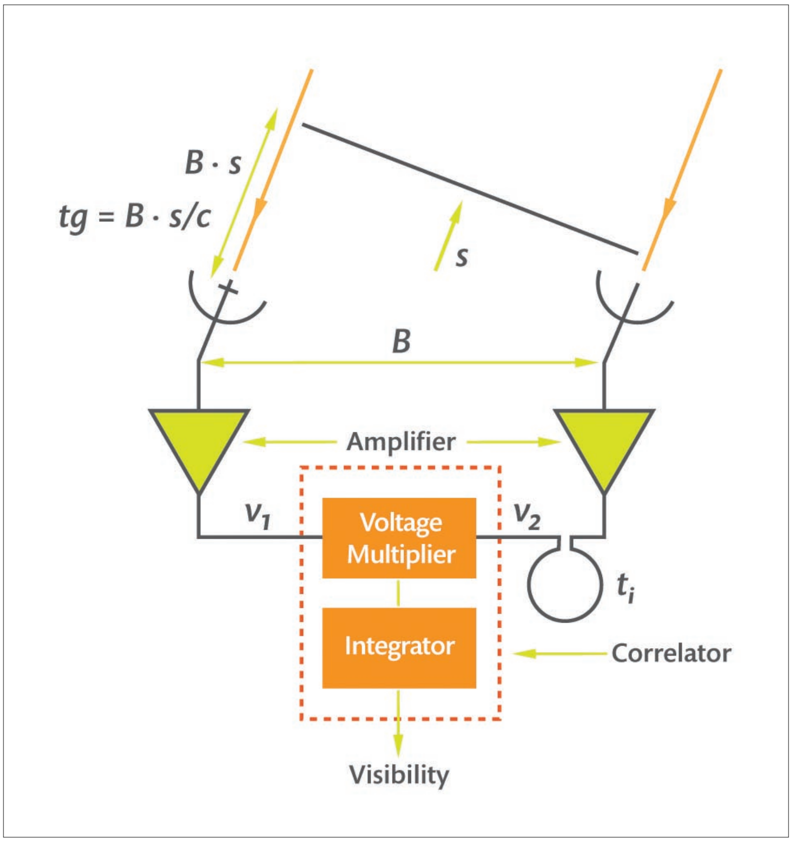
In Fig. 6 is a schematic of a single radio receiver of the type used in ALMA. These are referred to as heterodyne receivers. The system shown on the left has a box labeled "RF Amp". This is not present in the ALMA receiver Bands used so far but would be used in the lowest frequency receiver, Band 1, which will be working at such a low frequency that direct amplification is still possible. In ALMA, the final stage is not demodulation (detection with a square law device, that is, the output is the square of the input) but rather further processing of signals in the correlator. On the right are a series of sketches that show the time and frequency behavior of the signal voltage at each stage of the reception process. The topmost line is the signal received from the sky frequency (in the above example from 275-373 GHz). The time behavior shows very rapid variations. The next line shows the behavior in time and frequency if one would amplification at the sky frequency in a rather narrow range of frequencies. Here the time variations of the sky frequency input, are slower since the time variations are inversely proportional to the frequency range filtered out. On the next line, the center frequency of the input

A photo of the Technical Building at the AOS. The outputs from all ALMA antennas are brought to this facility for further processing.

ALMA In-depth







is lowered by the action of the mixer (in our example to a frequency range between 4 and 12 GHz). This is shown in the even slower oscillation time. The lowest two lines show the effect of the detection. There is an analogy for ALMA in that the variation of fringes in the correlation of two antennas is much slower than the variation of sky or IF frequencies.

One can consider a two element interferometer to understand the more complex ALMA system. On the left is a sketch of two elements. In the receivers, located after the antennas, there are a series of narrowly spaced parallel lines. These are frequency bands of 2GHz or less. This allows interferometric spectral line observing and also for continuum observation, since narrower frequency bands make signal processing simpler.

In the method shown, each of the antennas must be equipped with an identical set of filters. For a large system such as ALMA this would be a very formidable task. There is an alternative however (this is the system actually used for ALMA). In this approach, the outputs from the two antennas are sampled at equal times. These samples are shifted relative to each other in time and then multiplied. This process is referred to as correlation. When the correlated products are converted from time to frequency the results are completely equivalent to the setup with two sets of filters. However, the extension using this method to many antennas is rather simple. For the user of ALMA the complex scheme of amplifying, downconverting and processing of astronomical data will be very transparent (if he or she wishes) since the Observing Tool and the data reduction pipeline are designed to translate the scientific goals of ALMA users into system configurations and to convert the visibilities measured into image cubes.

ALMA Newsletter
September 2010

Credit: NRAO, The Twelfth Synthesis Imaging Workshop

ALMA Events

2010
- jun -
8/15

"Preparing for ALMA" in the NRAO Synthesis Imaging Workshop

A "Preparing for ALMA" session was held as part of the 12th Synthesis Imaging Workshop in Socorro on June 8-15, 2010 in Socorro, NM. Over 150 students participated in the Workshop which included tutorials on data reduction and on ancillary programs. Also, end-to-end user tests have been executed under the guidance of the JAO. These have included proposal submission, technical assessment, judgement before a mock review committee, generation of observing instructions ('schedule blocks') for successful proposals and proposal tracking.

Attendees at the NRAO's Twelfth synthesis Imaging Workshop listen to a presentation by Claire Chandler, Deputy AD and Head of the Array Science Center. The school comprised of a week of lectures on aperture synthesis theory and techniques, including two days of data reduction tutorials. There were 154 participants from 14 countries. A majority of the participants were graduate students but undergraduates, postdocs, scientific and engineering staff and faculty also attended.

Job Opportunities

There are positions for astronomers to be filled in Chile, both as members of the Commissioning Team and in Operations. Commissioning is part of the ALMA construction project and is of course focussed on getting all of the components fully working as a unique telescope and verifying the quality of the data coming out, so we are looking for people with particular interest in and experience of instrumentation and in-depth data analysis. The Science Operations team is now being built up and there are posts to be filled covering a wide range of activities, including instrumentation and data analysis but also planning and scheduling.

Advertisements for these posts will appear in due course on the ALMA website and those of the ALMA partners, but we are always pleased to hear from qualified people who are keen to join the science team in Chile. If you are interested and well-qualified (i.e. with a doctorate and relevant experience) please do contact either Alison Peck (apeck@alma.cl) or Lars Nyman (lnyman@alma.cl), rather than waiting for announcements to appear. In addition, there is a Visitor's Program in place for people who wish to participate in Chile for periods of about 3 months to a year.

ALMA Newsletter
September 2010

Upcoming events

2010 ASIA-PACIFIC RADIO SCIENCE CONFERENCE

2010
- sep -
22/26

The "2010 Asia-Pacific Radio Science Conference" (AP-RASC'10) will be held at Toyama International Conference Center, Toyama, Japan on September 22-26, 2010. The AP-RASC is the Asia-Pacific regional URSI conference held between the URSI General Assemblies. The objective of the AP-RASC is to review current research trends, present new discoveries, and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable, and a particular emphasis is placed on promoting various research activities in the Asia-Pacific area. Scientific sessions composed of oral and poster papers will be organized at this conference in order to cover all scientific activities by URSI Commissions A-K:

A: Electromagnetic metrology.
B: Fields and waves, electromagnetic theory and applications.
C: Radiocommunication systems and signal processing.
D: Electronics and photonics.
E: Electromagnetic environment and interference.
F: Wave propagation and remote sensing.
G: Ionospheric radio and propagation.
H: Waves in plasmas.
J: Radio astronomy.
K: Electromagnetics in biology and medicine.

Further details and a registration form are at:

Commission J: Radio Astronomy
J2: Millimeter- and sub-millimeter-wave telescope and array
http://www.ap-rasc10.jp/pdf/AP-RASC10_SecondCFP.pdf
Convener: Satoru Iguchi (NAOJ, Japan) and Nagayoshi Ohashi (ASIAA, Taiwan)

Dates: September 22-26, 2010. **Location:** Toyama International Conference Center, Japan.
More information: http://www.nrao.edu/meetings/comets10/index.shtml

ALMA Newsletter

September 2010

Upcoming events

7TH IRAM INTERFEROMETRY SCHOOL 2010

2010
- oct -
4/8

The 7th IRAM millimeter-interferometry school will take place from October 4th to 8th; it is intended for PhD students, post-docs and scientists who want to acquire a good knowledge of interferometry and data reduction techniques at millimeter wavelengths.

Dates: 4 to 8th October 2010. **Location:** IRAM headquarters. Grenoble, France.
More information: http://www.iram-institute.org/EN/news-astronomers/2010/24.html

GROTE REBER MEDAL

2010
- oct -
15

The Reber Medal for outstanding and innovative contributions to radio astronomy is a prize specifically for radio astronomy. The nominations for the 2011 prize close on **15 October 2010.**

The Reber Medal was established by the Trustees of the Grote Reber Foundation to honour the achievements of Grote Reber and is administered by the Queen Victoria Museum in Launceston, Tasmania. The 2010 Grote Reber Gold Medal has been awarded to Dr Alan Rogers, a Research Affiliate at the Massachusetts Institute of Technology Haystack Observatory. Rogers is being honoured for his many pioneering developments in radio and radar interferometry, radio spectroscopy, and for his application of radio astronomy techniques to society. The previous winners of the Grote Reber Medal have been Professor Bill Erickson (University of Maryland, 2005), Professor Bernard Mills (University of Sydney, 2006), Professor Govind Swarup (Tata Institute of Fundamental Research, 2007), Dr Sander Weinreb (Caltech–JPL, 2008) and Dr Barry Clark (NRAO, 2009).

To nominate an achiever in radio astronomy for the Medal, please send a covering letter and supporting material (e.g. CV and bibliography) to:

Martin George
Queen Victoria Museum and Art Gallery,
PO Box 403, Launceston, Tasmania 7250, Australia
or by e-mail to martin.george@qvmag.tas.gov.au .

Dates: October 15, 2010. **Location:** Queen Victoria Museum in Launceston, Tasmania.
More information: Grote Reber Medal homepage **http://www.qvmag.tas.gov.au/?articleID=539**

ALMA Newsletter

September 2010

Upcoming events

OBSERVING WITH ALMA - EARLY SCIENCE

2010
- nov -
29

The European ARC node at IRAM will be organizing a workshop on the ALMA Early Science, from Nov. 29th to Dec 1st. The goal of the workshop is to provide astronomers with the practical information needed to plan ALMA Early Science observations and answer the first Call for Proposals: status and performances of the instrument, preparing and submitting a proposal with the Observing Tool, etc.

Dates: 29 November to 1st December 2010. **Location:** IRAM headquarters. Grenoble, France.
More information: http://www.iram-institute.org/EN/news-astronomers/2010/25.html

OBSERVING WITH ALMA - SPECIAL SESSION

2011
- jan -
9/13

At the 217th AAS meeting in Seattle 9-13 Jan 2011 there will be a Special Session -- “Observing with ALMA”. The AAS has scheduled this session for Wednesday, 12 January 2011, 2:00-3:30 pm. Details will be forthcoming soon.

More information: http://aas.org/meetings/aas217

THE FIFTH NAASC WORKSHOP WILL HIGHLIGHT TRANSFORMATIONAL SCIENCE ENABLED BY MODERN HIGH RESOLUTION WIDEBAND SPECTROSCOPY.

2011
- jan -
15/17

The National Research Council of Canada (NRC), the North American ALMA Science Center (NAASC), and the Center for Chemistry of the Universe (CCU) will jointly host a major science conference titled ALMA: Extending the Limits of Astrophysical Spectroscopy in Victoria, British Columbia, 15-17 January 2011. The website is now open for registration: **http://www.almatelescope.ca/Spectroscopy2011/**

The capabilities of new Atacama Large Millimeter/submillimeter Array (ALMA) instrumentation will be highlighted at this meeting via invited science talks in astronomy, astrophysics, and astrochemistry.

Over the next several years, the NRAO research facilities will provide the scientific community with unprecedented advances in high spatial resolution, broadband observing capabilities over frequency ranges that are sparsely covered by other facilities. ALMA will be capable of

Upcoming events

recording more than 2 GHz of instantaneous bandwidth at high spectral resolution and will routinely deliver high fidelity, high spatial resolution astronomical images. Spectroscopy is a vital tool to improve our understanding of the Universe, enabling scientists to probe physical and chemical environments, investigate kinematics and dynamics, and explore the high red-shift Universe while also obtaining abundances, concentrations, and temperatures of exotic molecular species.

In conjunction with the Spectroscopy conference, those arriving early on 14 January are invited to attend a panel discussion on ALMA Development, and on 17 January following the conference there will be an optional tour of the Herzberg Institute of Astrophysics.

Specific focus areas for this science conference will include:

* The Atomic Universe: Atomic Spectra as Probes of Cool Gas
* The Molecular Universe: Dense Star-forming Gas
* Isotopic Variety in Interstellar Medium
* Our Molecular Origins: Prebiotic Molecules

Confirmed Invited Speakers:

* Darek Lis - Caltech
* Christine Wilson - McMaster University
* Ted Bergin - University of Michigan
* Stefanie Milam - NASA's Goddard Space Flight Center
* David Neufeld - John Hopkins

Dates: 15-17 January 2011. **Location:** National Research Council of Canada, Victoria, British Columbia
More information: http://www.almatelescope.ca/Spectroscopy2011/

ALMA Newsletter

September 2010

High in the Chilean Andes, at 5000 metres above sea level, one of the giant Atacama Large Millimeter/submillimeter Array (ALMA) antenna transporters contemplates an unexpected sight — a delicate dusting of snow whitens the breathtaking landscape of the Chajnantor plateau, home of the ALMA project. Snow is a very rare event at this extremely arid site and is a consequence of the Altiplanic winter, caused when the jet stream reverses and comes from the chill east. Chajnantor is one of the driest sites in the world, making it excellent for astronomical observations. The hill in the background is Toco, a 5600-metre mountain toward the north. This image was taken on 30 April 2010.

ALMA (ESO/NAOJ/NRAO)

ALMA

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To find out if you are already on the email list, send an email to almanewsletter@alma.cl, with *"which"* in the body.

This newsletter is also available here.

Please send comments on the newsletter or suggestions for articles and announcements to the editors at:

William Garnier (wgarnier@alma.cl)
Rainer Mauersberger (rmauersb@alma.cl)

More information on ALMA and contact details can be found on the ALMA homepage www.almaobservatory.org

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