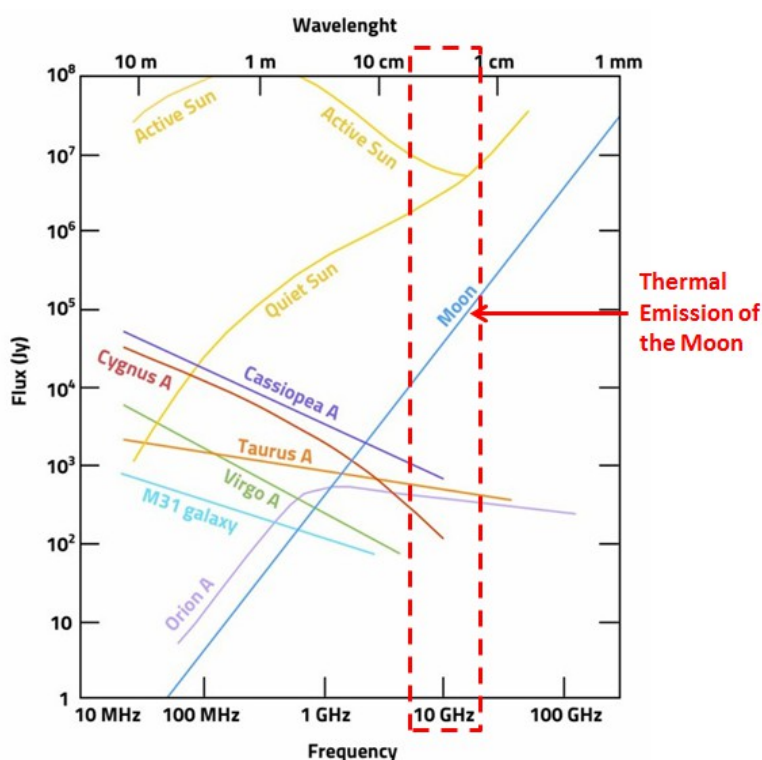


Observing the microwave radiation of the Moon with RAL10

Flavio Falcinelli

RadioAstroLab s.r.l. 60019 Senigallia (AN) - Italy - Via Corvi, 96
Tel: +39 071 6608166 - Fax: +39 071 6612768
info@radioastrolab.it www.radioastrolab.it www.radioastrolab.com

Is the Moon a source of radio waves? If so, is it detectable by amateur means?
Yes, its radiation is easily measured when operating in the microwave band. The reason is clear by looking at the following chart that shows the radio spectra of the most important sources observable with small amateur telescopes: the curves describe how the emission intensity varies at different frequencies.



Pic. 1: Spectrum of the radio emission of the Moon: a curve rising with the frequency indicates the thermal nature of the mechanism of radiation (similar to a black body with a physical temperature of the order of 200 K). Unlike most radio sources that exhibit a non-thermal emission mechanism, decreasing with increasing frequency, the radiation of the Moon is easily observable in the operating band of the radio telescope RAL10.

The Moon behaves similar to a black body with a temperature of about 200 K: as every "hot" object, it emits electromagnetic radiation due to the motion of agitation of the atoms that compose it (Planck's radiation law). This emissive feature, with increasing intensity at increasing frequency, makes the moon an easily visible object to the operating frequency of the radio telescope RAL10 (11.2 GHz). While in the visible the emission of the Moon is almost exclusively due to the reflected light of the sun, its radiation in the microwave, measurable with amateur equipment, is due almost exclusively to its physical temperature.

Unlike other very active celestial bodies as the Sun, characterized by a complex radio emission that essentially includes a continued thermal component (quiet Sun) and a variable component linked to the presence of activity centers on the disk (bursts, flares, etc.), the "radio-Moon" is absolutely quiet and monotonous, without observable transient phenomena. This does not diminish the interest towards this object: it is instructive, for example, to study how the lunar radio emission differs to the varying of the percentage of illumination of the disk (stages) or during an eclipse, since its signal will always be recordable even when our natural satellite is not visible in the sky.

We describe a simple experiment of recording the microwave thermal radiation (band 10-12 GHz) during a lunar transit. We used a small radio telescope consisting of an offset parabolic antenna, the type used for satellite reception in the band 10-12 GHz, diameter approximately 70 cm, equipped with the external unit RAL10_LNB and the receiver RAL10, both thermo-stabilized. The sensitivity and stability of the receiving system are, undoubtedly, a great advantage for the quality and repeatability of the measurements: it is known how the variations of the received signal due to temperature variations represent, especially for the external unit and for the receiver, a factor which limits the reliability of our observations. Precisely for this reason, we used a receiving system with a controlled internal temperature: when we will record changes in the signal, we will have a reasonable assurance that these are due to variations in the brightness temperature of the scenario "seen" by the antenna and not artifacts of the receiving system.

The following pictures describe the instruments, very simple, inexpensive and handy.



Pic. 2: The radio telescope used in the experiment: you can see the antenna (a common offset parabola for TV-SAT 10-12 GHz of 70 cm) equipped with the external unit RAL10_LNB and the receiver RAL10.

The observation is in the transit: we establish the future position in the sky of the "target" and orient the antenna in that position, waiting to record the emission peak when the object passes in front of the beam of reception of the radio telescope.

The antenna pointing system is manual, very elementary: knowing the future position of the Moon (acquired using one of the many programs available in the web - Fig. 7), you move the antenna in elevation and azimuth with the help of an bubble inclinometer (elevation) and with a common goniometer (azimuth), previously fixed to the supporting structure. This is a very simple system for the orientation of the radio telescope. Since the amplitude of the reception lobe of the antenna is hardly greater than 3 degrees, while the apparent size of the moon is of the order of half a degree, it should be paid a minimum of attention in orienting the system in the correct direction, otherwise we get a false registration or a significant reduction in the intensity of the signal if the telescope does not "see" exactly the heavenly "target".

Manual orienting of the offset parabolic antenna for TV-SAT (10-12 GHz) with 70 cm diameter.

Movement in azimuth of the antenna with a simple goniometer.

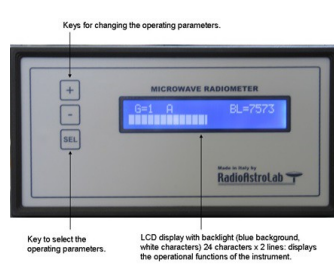
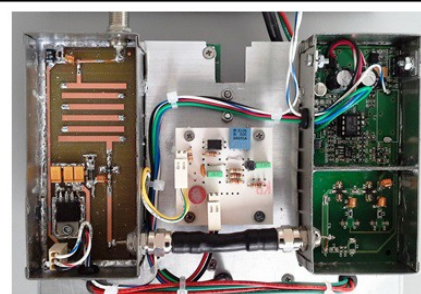
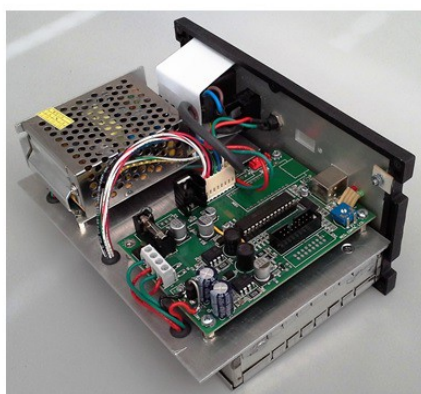
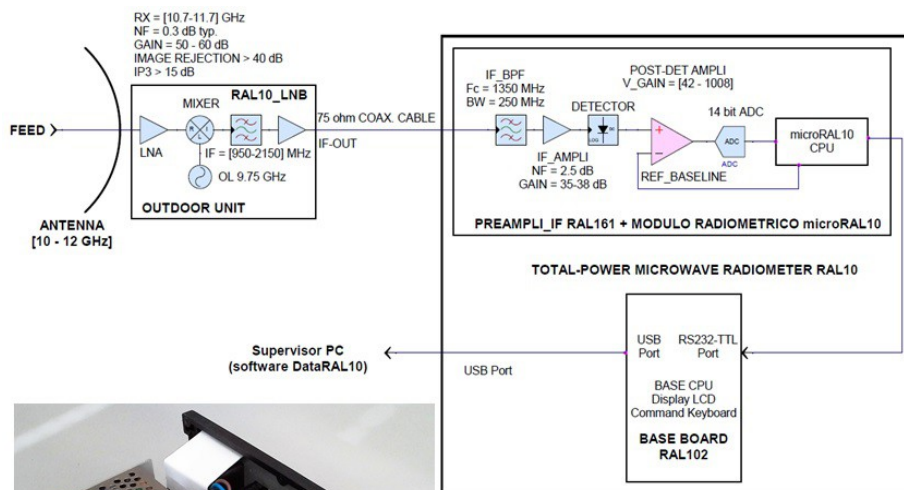


Movement in elevation of the antenna with a bubble inclinometer.

Pic. 3: Orientation system of the antenna: it is a simple amateur realization where the pointing is realized manually by controlling the elevation and displacement in azimuth of the beam of reception so that it is coincident with the future position of the Moon, at the given instant of the fixed day.

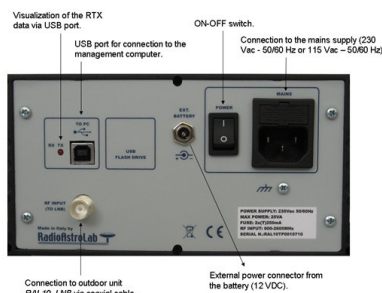
Given that the installation site of the radio telescope, due to the presence of buildings, the polar star is not observable for a correct orientation of the position reference of the instrument, it has been used the position of the sun on a clear day, known at a given instant, to orient the antenna in its direction, using the focused image of the disc projected in center of the mouth of the illuminator. In this way it was possible to fix the indicators and the references of the elevation and azimuth scales so as to match the values with the known locations. Once the references were fixed, it was possible to adjust the antenna towards the future position of the Moon, with an acceptable approximation at an amateur level.

The experiment took place in a cloudy and humid day, with the antenna oriented in the sky direction planned to intercept the passage of the Moon at 5:43 UTC on December 4th 2015. At the time of the transit, the percentage of illumination of the Moon was well below 50%.



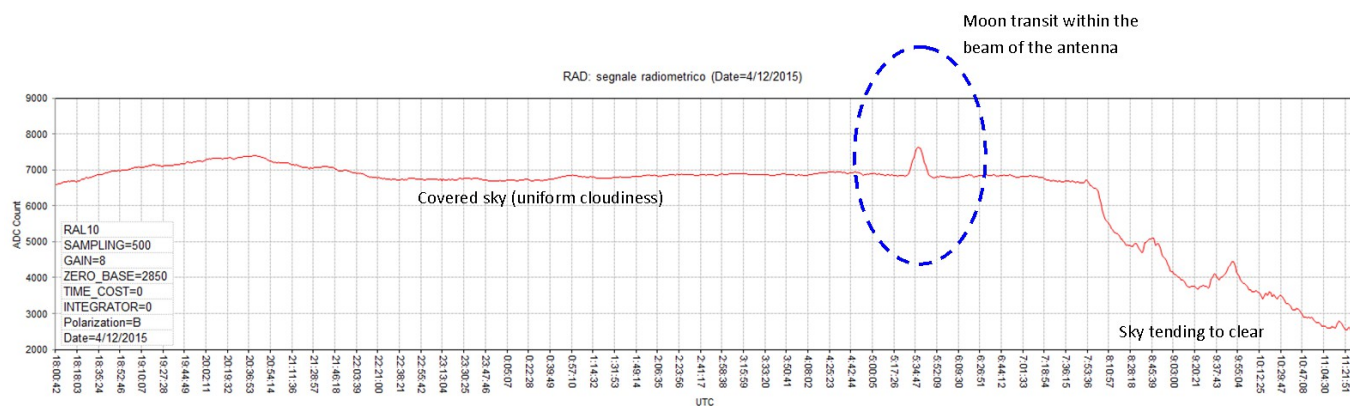
The receiver is thermally stabilized (to optimize the reproducibility and accuracy of the measurement). It has a front panel with keypad for manual setting of the controls and a backlit LCD display for displaying functions. A USB port connects the PC station managed by the supplied software.

RAL10 is a *Total-Power* radiometer characterized by high sensitivity and stability, as required by the most advanced amateur radio astronomy observations. The wide possibility of programming and control the operating parameters make it the tool tip of the *RAL10* family.



Pic. 4: Radio Telescope at 11.2 GHz based on the receiver RAL10: block diagram, external unit RAL10_LNB installed on the focus of the antenna and interior parts of the receiver.

The pictures 5, 6 and 7 show the details of the observation: the graph of Pic. 5 shows an "overview" of the measurement session began on the afternoon of the previous day, in a weather condition without rain, ended a few hours after the transit, with weather tending to clear.



Pic. 5: Recording of the measurement session.

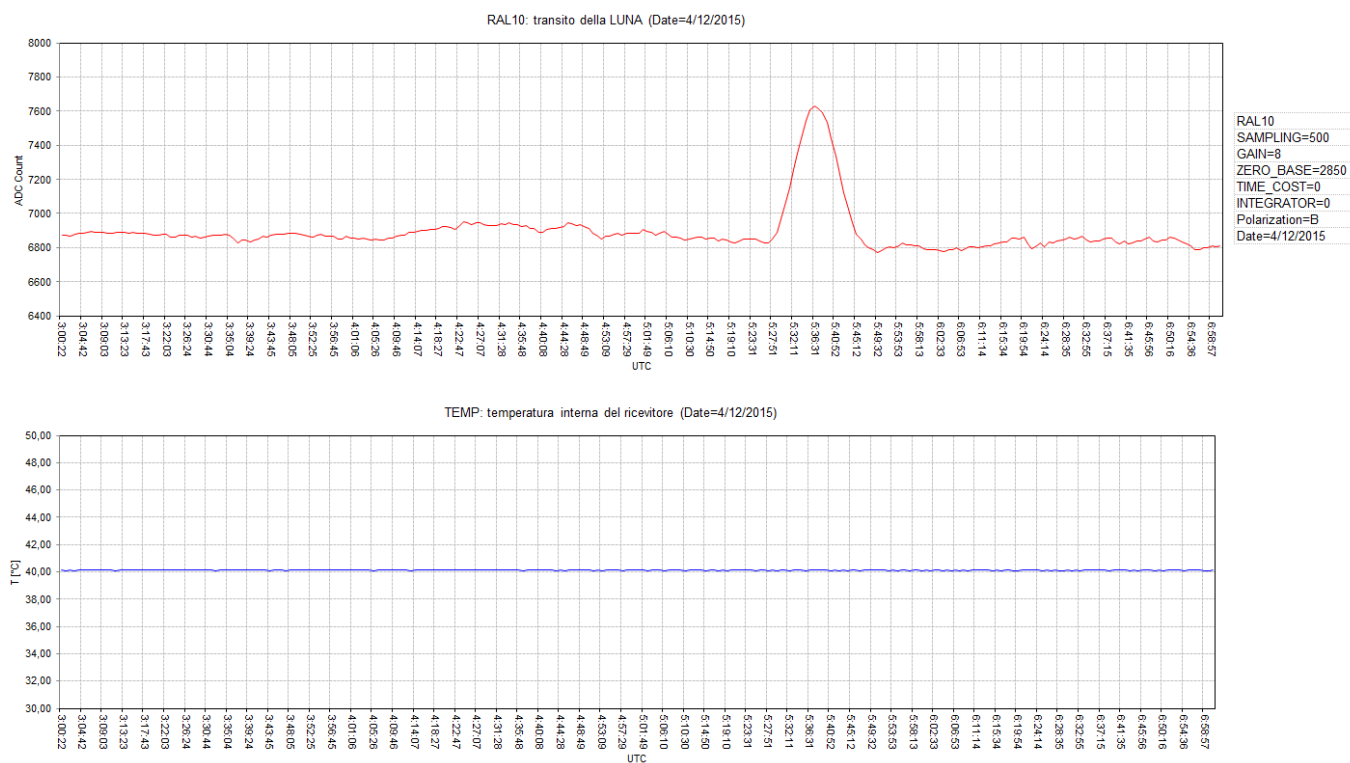
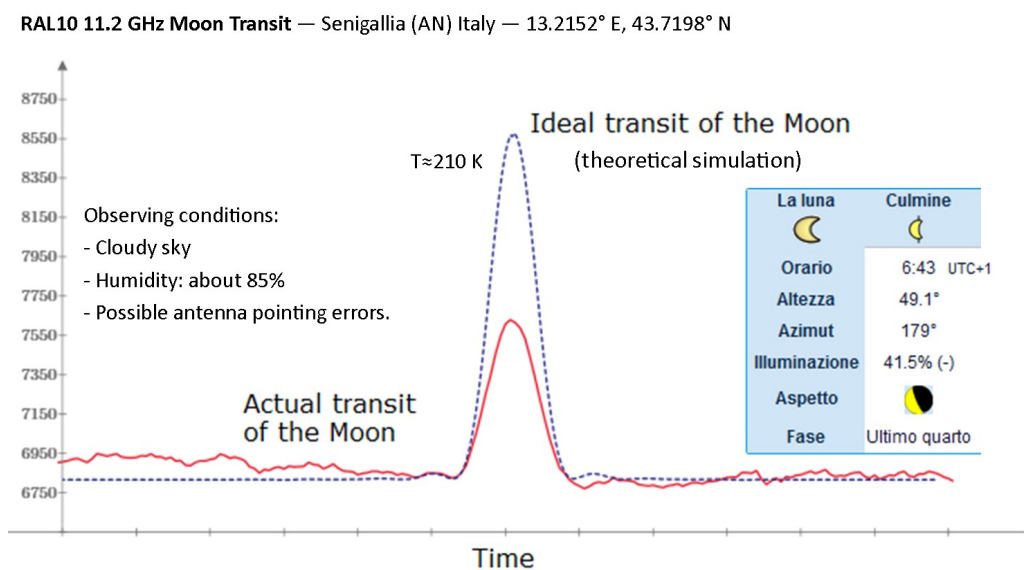


Fig. 6: Details of the lunar transit within the beam of the antenna. The graph below shows the inner temperature of the receiver RAL10 stabilized at about 40 ° C (automatic control PID).

The details are shown in the following graphs: in Pic. 7 is also reported a comparison between the expected theoretical curve of the lunar transit (ideal, simulated) and that actually observed. In the simulation we considered the operating parameters and the response of the radio telescope measured in the laboratory, the ideal characteristics of the antenna and of the radio source.

Besides the signal attenuation, due to the noise contribution of the atmosphere (cloudy weather), the efficiency of the antenna system (estimated at about 50%) and in the presence of noise coming from the soil picked up by the side lobes (estimated to the order of 12 K, also due to the presence of nearby buildings), it is shown how possible (and probable) pointing errors of the instrument can help to significantly reduce the level of the received signal.

An interesting extension of the experiment consists of several recordings of the lunar transit, possibly in similar weather conditions, to the vary of the percentage of solar lighting of the disk (moon phase) and during eclipses. For best results it is important to optimize the orientation system of the antenna: if the "target" is not exactly framed by the reception lobe, you will record a distorted and attenuated profile.



Pic. 7: Comparison between the actual transit curve and the expected one (simulated) of the Moon.

Doc. Vers. 1.0 del 09.12.2015
@ 2015 RadioAstroLab

RadioAstroLab s.r.l., Via Corvi, 96 – 60019 Senigallia (AN)
 Tel. +39 071 6608166 Fax: +39 071 6612768
 Web: www.radioastrolab.it Email: info@radioastrolab.it

Copyright: diritti riservati. Il contenuto di questo documento è proprietà dell'autore. Nessuna parte di questa pubblicazione può essere riprodotta in qualsiasi forma o con qualsiasi mezzo senza il permesso scritto di *RadioAstroLab s.r.l.*