Observations of the 28 September 2015 Lunar Eclipse with the DL0SHF Radio Telescopes

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September 2015

Expectations

In 1949 Piddington and Minnett found by measuring the lunar radio emission that the maximum of the surface temperature of the Moon occurs not at Full Moon, but about 4 days later. This is because the lunar surface is not solid rock which heats quickly under the solar radiation, but is of broken-up composition of dust, sand, and small pebbles, known as 'regolith'. Because of its slow thermal response to illumination by the Sun, one expects that the few hours of a lunar eclipse do not appreciably alter the lunar surface temperature, as would be measured by the radio emission of the entire Moon.

Sensors placed on the Moon by the Apollo missions did record a temperature drop during an eclipse. However these measurements pertain only to the top layer of the regolith and not the deeper layers whose thermal radiation dominates in the radio emission.

Perhaps some effect of the eclipse might be detectable at, for instance, high frequencies which might be more sensitive to the top layers … ?

Observational Details

Since the main interest is to detect any variation of the radio flux during the eclipse, the procedures are quite simple: The Moon is tracked by every antenna and the radio flux is continuously recorded. Observations start shortly after moon rise, as to have a good amount of data from the unobscured Moon. This allows to judge the level of signal variations due to the receiver electronics and the sky. Fortunately, during the entire night, the sky is clear without any cloud.

The eclipse takes place when the Moon is already on its descent to the west. The first contact with the Earth penumbra occurs at 0011 UT, the Moon enters the core shadow at 0110 UT, it leaves the core shadow at 0430 UT and has the last contact with the penumbra at 0522 UT, setting a little later.
It is completely covered by the core shadow between 0212 and 0326 UT.

Measurements are taken with the DL0SHF antennas on 1.3, 8, 10, and 24 GHz. As atmospheric absorption is rather strong on 24 GHz, measurements of the empty sky (about 5° east of the Moon) are taken every one of two hours.
Unfortunately due to an error in the path name for the output file, the data taken on 8 GHz is not recorded. However, inspection at frequent intervals shows that the signal level has no significant variations. About two or three sudden jumps in signal level are noticed, unrelated to the eclipse, and most probably caused by bending of the coaxial cables – which is a known phenomenon on this antenna.

Results: 1.3 GHz

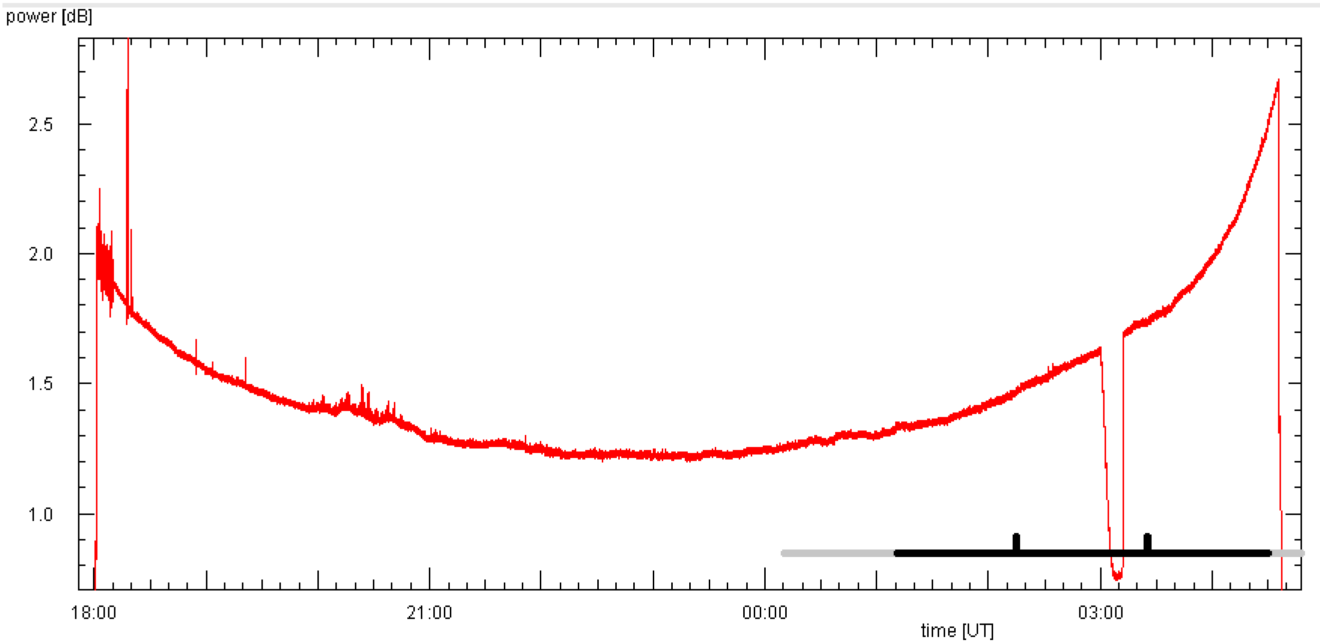

Fig. 1 *Signal level recorded on 1.3 GHz. The grey horizontal bar indicates the time during which the Moon is in the penumbra the black bar when it is in touch with the core shadow. The two black ticks mark the interval when the Moon is fully in the core shadow.*

Figure 1 shows the complete record. Since this antenna has a rather broad beam of 1.8° and also important side lobes, the signal level is high in the beginning and at the end due to pick-up of ground radiation. At the start, there is also a short period when the averaging had not been set to the customary 16, a short high peak probably due to a bird. Between 2000 and 2100 UT some signal variations are seen, perhaps radio interference.

Throughout the eclipse, the signal level does not show any significant variation, except for the systematic increase of the ground pick-up. At 0300 UT the tracking stops for an unknown reason, but without any indication for a fault or motor overload. It takes some time until the responsible program (AzElTracker) could be convinced to resume its duties. But since during this time the antenna points to the empty sky, the drop of signal level may serve as sky noise measurement. This gives a Moon/Sky contrast of 1.03 dB, which is as expected with this antenna.

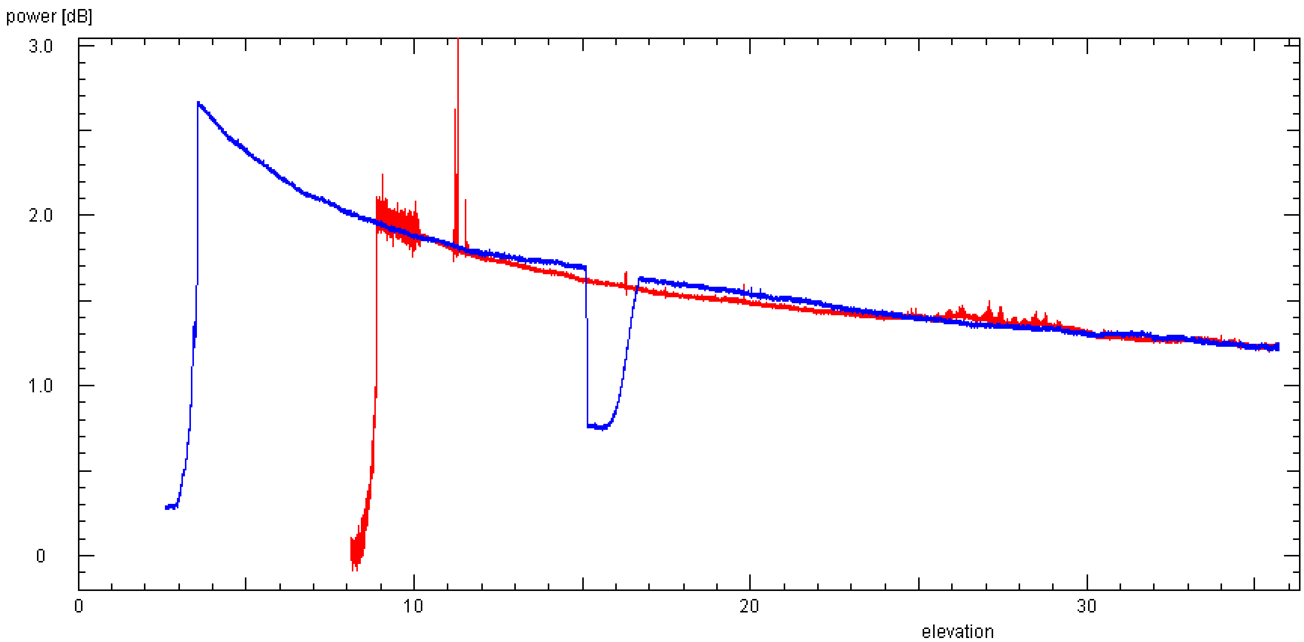

Fig. 2 *Signal level recorded on 1.3 GHz as a function of elevation. The western part is in blue.*

Comparison of the signal level from the eastern and western parts of the lunar track (Fig.2) reveals nearly identical profiles. During the eclipse on the western part the level is slightly higher (by as much as 0.1 dB), but this is obviously an instrumental effect or due to the variations of the sky foreground. If it would have been due to the eclipse, one should have seen a drop in signal. Unless the Earth shadow is a bit warmer than than the ambient sky …

Results: 8 GHz

As had been mentioned earlier, the data unfortunately was not recorded. Several inspections throughout the night did not show any significant level variations. The data looked very much like those on 10 GHz.

Results: 10 GHz

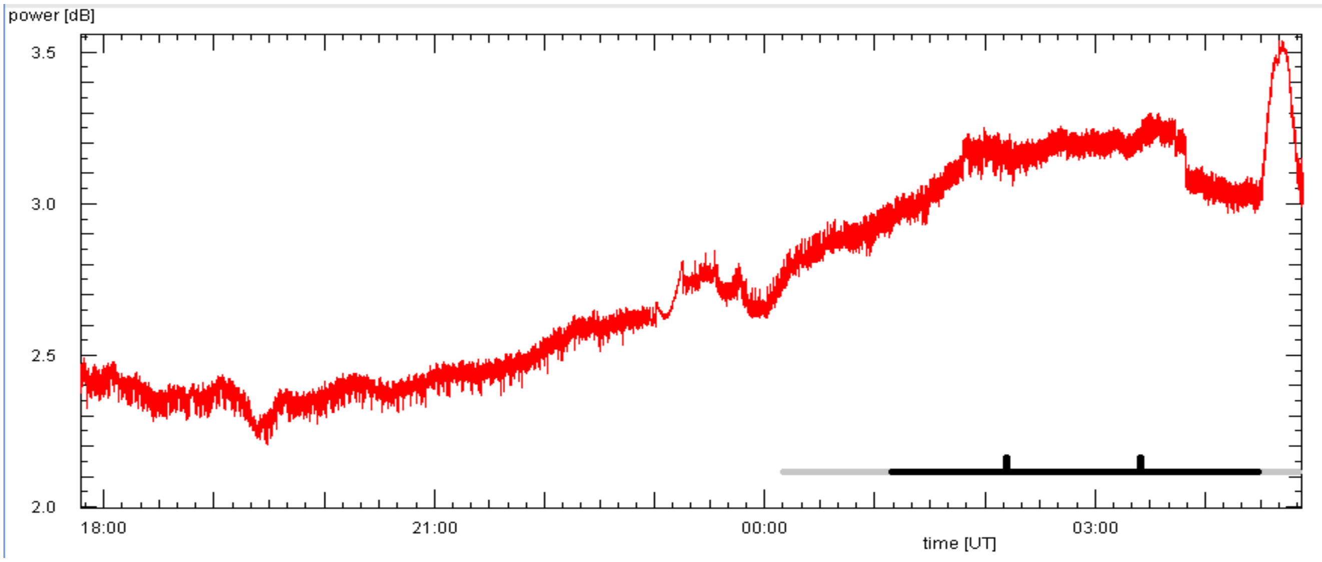

Fig. 3 *As Fig. 1, but for 10 GHz.*

The level measured on 10 GHz shows a somewhat systematic increase (Fig.3). As on this frequency thermal emission from the atmosphere is quite important, this may be due to a change in the atmosphere, but could also be a variation of the receiver noise as the electronics cools off during the night. In any case, there is no relation with the lunar eclipse. In particular, there is no reaction – in the form of a drop in signal – which starts when the Moon enters the core shadow near 0215 UT! The sudden drop in level at 0350 UT is clearly an instrumental effect. The rise near the end of the recording is due to the antenna pointing into some trees to the west.

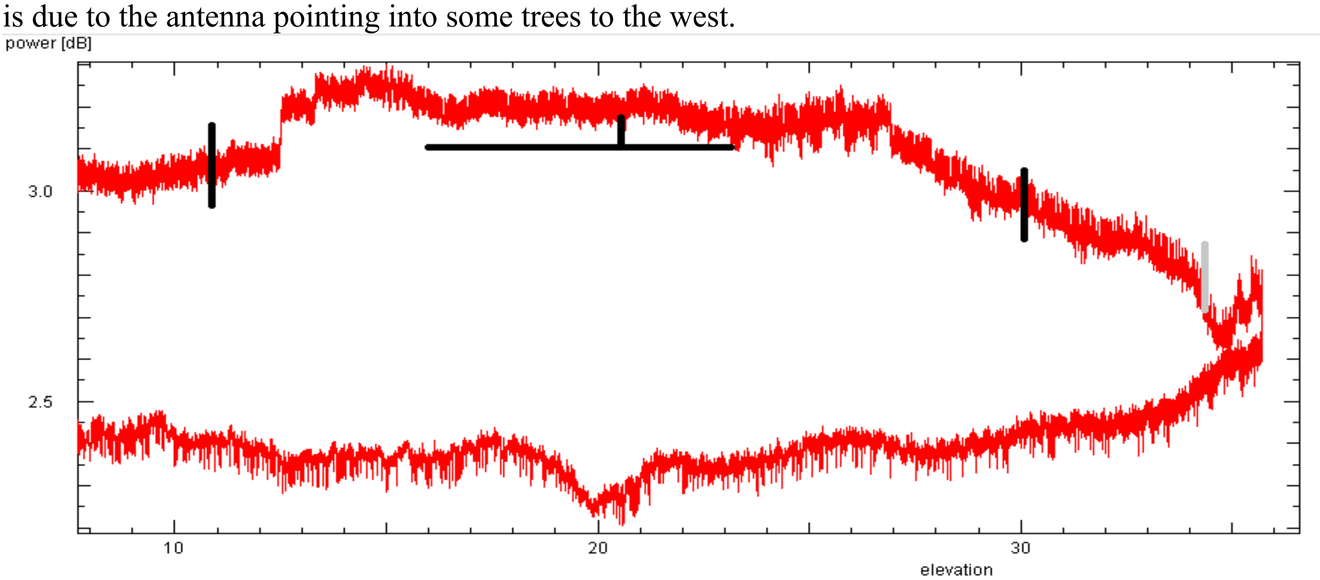

Fig. 4 *The dependence of the signal level with elevation. The vertical ticks mark the first contact (grey), entering and leaving the core shadow (black). The horizontal black line indicates the time when the Moon is fully covered by the core shadow, the vertical tick marks the maximum eclipse.*

From Fig. 4 it is apparent that there is no change of the level with elevation. At 10 GHz atmospheric absorption may also be neglected. There is no change that can be associated with the eclipse.

Results: 24 GHz

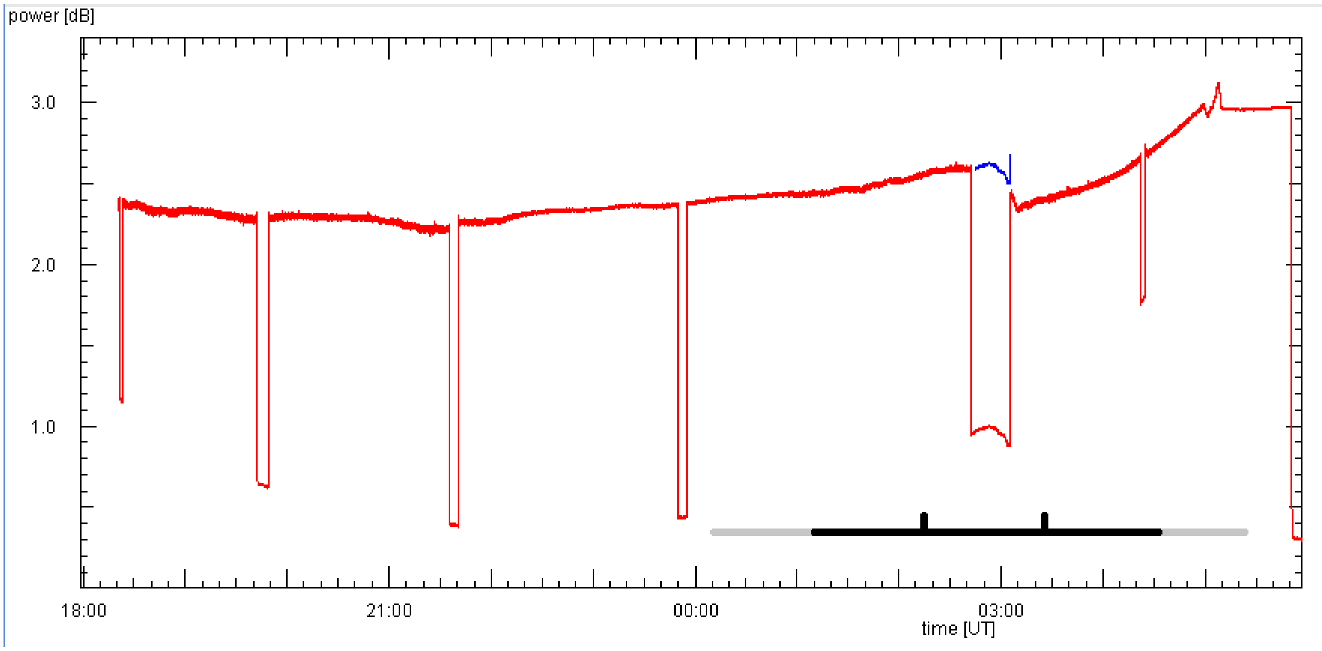

Fig. 5 *As Fig. 1, but for 24 Ghz. The regular signal drops are measurements of the sky 5° east of the Moon. The blue piece of curve is a copy of the curve below from the sky measurement (cf. text).*

On 24 GHz there is a slight fall and rise of the signal level (Fig.5), due to the absorption by the Earth atmosphere, which increases towards low elevation. At some times the antenna is moved about 5° east of the Moon to measure the empty sky. At 0240 UT, near maximum eclipse, one of these calibrations is taken, which is longer than the others because optical images of the dark moon are taken. By chance, during this time, there is a substantial variation of the signal level, which results in an overall drop by about 0.2 dB. However, this is a purely instrumental effect, because the change is present in the measurement of the empty sky: If one copies this part of the curve and places it at the part representing the lunar measurements, one finds that this piece (blue in Fig. 5) matches very neatly the evolution of the lunar signal. Therefore, the lunar radio emission on 24 GHz does not change during the eclipse.

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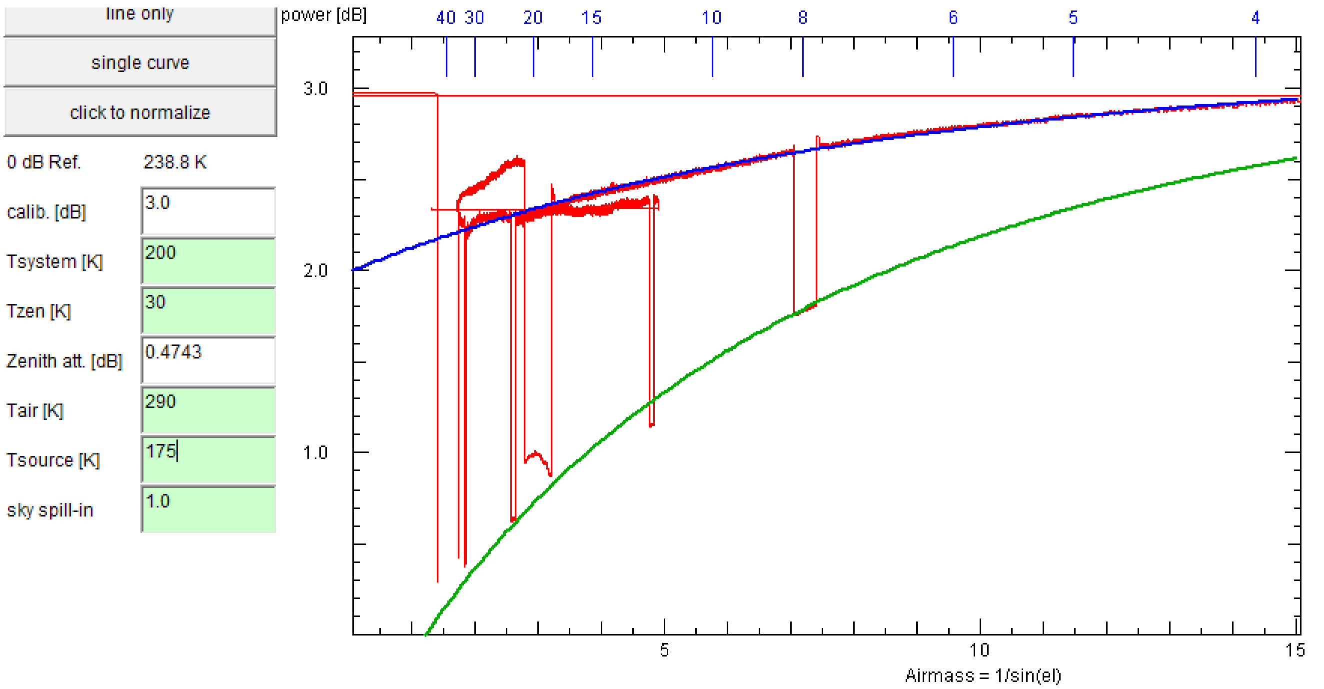

Fig. 6 *Interpretation of the lunar and sky measurements (red curve). The green curve is the dependence of the sky noise with elevation predicted by a simple atmospheric model. The blue curve is the match of the lunar radio fluxes. The blue numbers on top give the elevations for the abscissa, which is in airmass = 1/sin(elevation).*

Since at 24 GHz atmospheric absorption is very important, one can use the data taken at the Moon and the sky nearby to determine the atmospheric conditions (Fig. 6). Adopting the system temperature of 200 K from previous measurements, and assuming a plane-parallel layer of air at temperature 290 K, one finds that the measured dependence of sky noise on elevation can well be matched by a zenith absorption of 0.47 dB, corresponding to a zenith temperature of 30 K. Both values are in good agreement with previous observations for clear sky conditions. The lunar fluxes yield a lunar antenna temperature of 175 K.

Tracking Noise

What is meant by saying "no signal detected"? As can be seen in Figs. 3 and 5, the recording is a noisy curve. Part of this noise is due to the fact that the tracking of the antennas is updated only after the position has changed by at least 0.02° in azimuth or elevation. This is rather important for the 10 GHz antenna (Fig.7) because the main lobe is smaller than the Moon. Near meridian passage, the update in elevation beam occurs rarely (once in 15 min), so that the residual position difference is mapped in the registration. The receiver noise is only about 0.01 dB, far below the tracking noise of as much as 0.05-dB. This issue is less severe for the 24 GHz antenna (Fig.8).

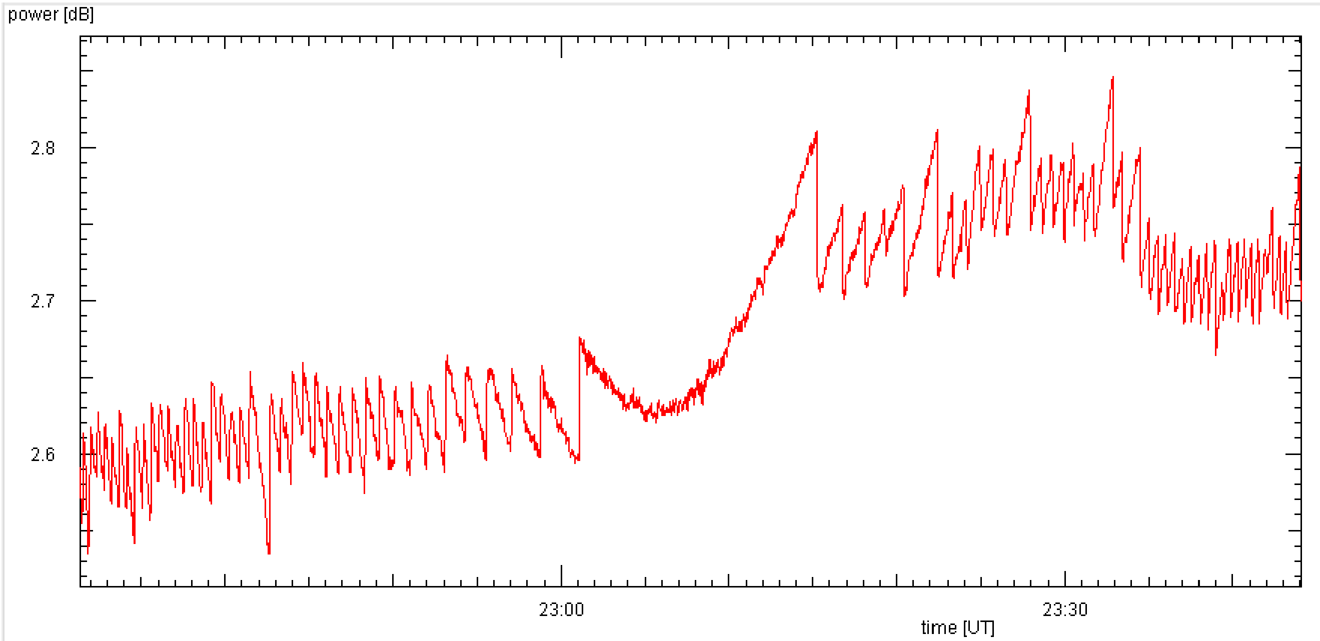

Fig. 7 *Detailed view of Fig.3, around the time of lunar culmination in the South.*

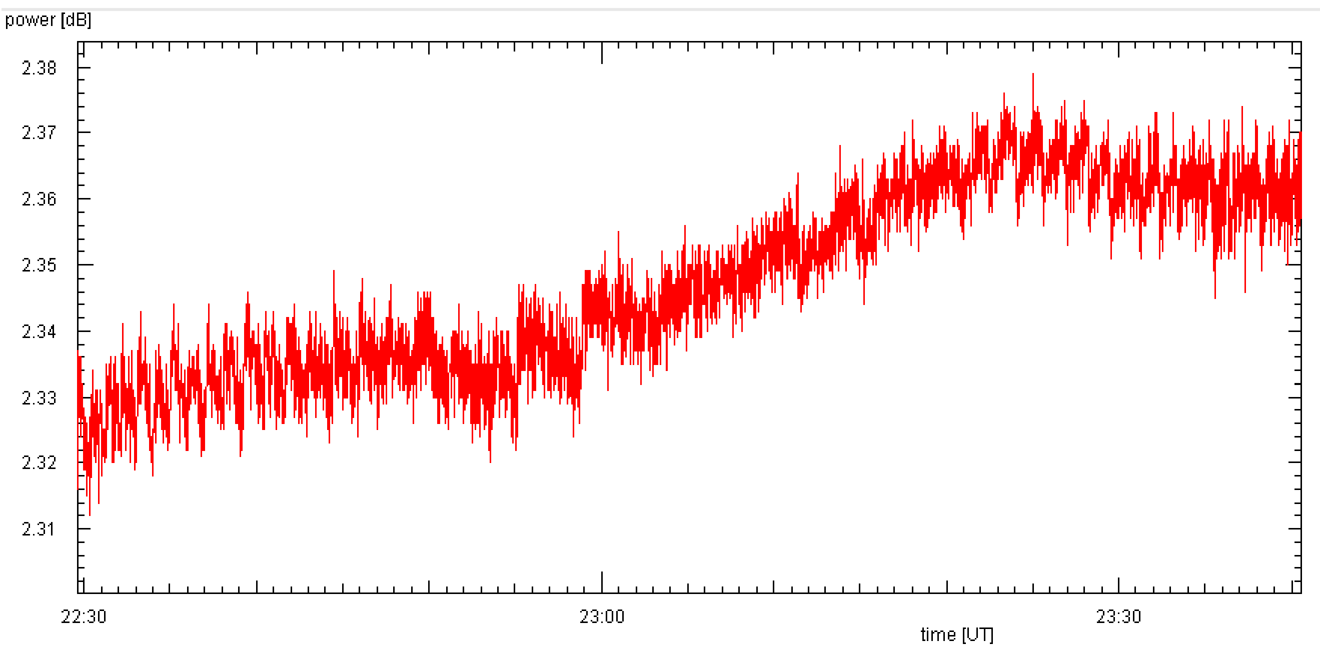

Fig. 8 *Detailed view of Fig.5, near meridian passage of the Moon.*

Conclusions

- Measurements of the lunar radio emission on 1.3, 8, 10, and 24 GHz do not show any change of the level during the total lunar eclipse, related to the eclipse
- No change of behaviour with frequency is detected

This confirms that the Moon's thermal radio emission and hence the temperature on the lunar surface does not change as rapidly as a few hours. This time scale must indeed be several days, as evidenced by the observed delay of 4 to 5 days between maximum temperature and Full Moon.