38. **Lunar Radiation at 3,000 Mc/s**

By Kenji AKABANE
Tokyo Astronomical Observatory
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1. **Introduction**

The microwave radiation from the moon was first detected by Dicke at 24,000 Mc/s. Later Piddington\(^1\) and Minnett observed at the same frequency and found its variation with the phase of the moon. They calculated the variation of the temperature at the center of the lunar disk and also remarked the pronounced delay in the time of maximum temperature when compared with the optical full moon. From their observation combined with the observation in the infrared region, they proposed a model for the surface structure of the moon. Recently J. C. Jaeger\(^2\) proposed another model for the lunar surface. It is the purpose of the present investigation to extend the lunar observation to a much lower frequency region.

2. **Apparatus and Calibration**

The observation was carried out with the equatorial parabolic reflector of 10 meter diameter recently built in the Observatory. The central frequency of the receiver is 3,000 Mc/s and the image band is also received together with the signal band. The intermediate frequency amplifier has the central frequency of 30 Mc/s with the band-width of 5 Mc/s. In order to switch between the antenna noise signal and the standard noise level (radiation at the ambient temperature) a pin is rotated in the wave guide at 25 c/s instead of rotating an absorbing disk. The modulated signal is fed to a phase sensitive detector of 25 c/s and its D-C output is fed to a 5mA pen recorder. Fluctuations on the recorder chart correspond to the aerial temperature about 7°K with the over-all time-constant of 1 second. The antenna beam shape and its central gain are measured by using a 2 meter parabolic reflector. The 2 meter parabolic reflector has the central gain of 1,350, which is calibrated by a rectangular electromagnetic horn having the central gain of 159±5%, referred to an isotropic radiator. In these measurements the sun was used as a power source, and in the analysis of the beam shape the radio brightness distribution over the solar disk observed by Covington\(^3\) at 2,900 Mc/s was adopted. Fig. 1 shows the derived beam shape of the 10 meter reflector, which is the mean value of
the $E$ and $H$ planes, the $E$ direction being perpendicular to the polar axis. The error in the gain thus obtained is estimated to be about \( \pm 10\% \), which is to be attributed to the calibration error and the inaccuracy of the standard horn. When the reflector is directed to the zenith the receiver output corresponds to 0°K within the experimental error. Although in this procedure appreciably large errors might be introduced by the leakage of the ground emission through the paraboloid and the mismatching between the feeder and the reflector, these uncertainties are checked by another horn which is placed at the top of the wave guide instead of the feeder and directed to the zenith exactly. This horn has a voltage standing wave ratio of 1.05 over the required band of frequency when connected to the wave guide. Atmospheric effect on this frequency is found to be negligible by similar measurements. Another temperature scale on the receiver output is determined by inserting an absorber of the ambient temperature in the wave guide. This absorber has also a voltage standing wave ratio of 1.05. The linearity of the receiver was checked by assuming the output of the second detector to be linearly proportional to the input noise voltage. The last assumption may cause an error of less than 6% in the antenna temperature. Moreover the over-all linearity of the receiver was measured by the hot-load experiment.

3. Observational Results

Thirty-nine observations were made during August and September, 1954. The observational aerial temperature at each experiment is plotted against the lunar phase in Fig. 2. The reading error on the recorder chart of a single measurement is estimated to be 4°K in the aerial temperature, and the scattering of these points in Fig. 2 might be due to the accidental errors in the observation and the reading. From these observational data the maximum and the minimum aerial temperatures of the moon are estimated to be about 30°K and 20°K respectively. It is also noted that the maximum temperature is observed a few days after the full moon.

4. Discussions

Since the beam width of the 10 meter reflector is about 40 min. of arc at 3,000 Mc/s and comparable with the diameter of the moon, which is about 32 min. of arc, the actual temperature distribution over the lunar surface is deduced in the following way. For simplicity we assume the effective temperature distribution on the lunar spherical surface as follows.

$$ t(\lambda, \phi) = t_0 \cos^{\frac{5}{6}} \phi \left[ 1 + a \cos (\lambda - \lambda_0) \right], $$ (1)
where \( t_0 \) and \( \Delta t_0 \) represent the average temperature and the amplitude of the temperature variation along the lunar equator and \( \lambda \) and \( \phi \) are the lunar phase angle and the latitude respectively. \( \lambda \) is measured from the center of the lunar disk at the time of the full moon. The temperature used here should be understood as the product of the emissivity and the actual temperature at the lunar surface, when the emissivity is not equal to unity. In the case when the center of the lunar disk has the maximum temperature, the equation (1) is integrated numerically with the antenna gain function shown in Fig. 1 for the assumed value of \( a \). Thus calculated antenna temperature should be equated to the maximum aerial temperature of 30°K in Fig. 2. The curve (a) in Fig. 3 shows the equatorial temperature calculated by putting

\[
t_0 = 315^\circ, \quad a = 0.24, \quad \lambda_0 = 45^\circ
\]

in equation (1). Equation (1) is again integrated by assuming the values given in equa-

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**Fig. 1.** Estimation of the gain of the parabolic reflector (calibrated from the quiet sun at 3,000 Mc/s and referred to an isotropic radiator)

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**Fig. 2.** Observed results and the calculated antenna temperature

- Calculated value from eq. (1)
- Observed value
tion (2) over the lunar disk by multiplying the gain function deduced in 2. The dotted curve in Fig. 2 gives the resulting curve and shows fairly good agreement with the observed values.

For the sake of comparison the variation of the lunar temperature is shown by the curve (b) in Fig. 3 when the effective temperature is assumed to be uniform over the lunar disk. The small difference between curves (a) and (b) is to be attributed to the relatively large beam width of the 10 meter reflector to the diameter of the moon, and so the temperature distribution given by equations (1) and (2) is not too much stressed. The errors in equation (1) are estimated to be about less than 50°K, which are introduced both from the estimation of the antenna gain and from the accidental errors of the experiments. The result by Piddington and Minnett at 24,000 Mc/s is also shown by the curve (c) in Fig. 3. It is to be noted that the present observation gives the effective temperature higher than the temperature they obtained, although for the final value of the difference in temperature at these two frequencies we must wait for further investigations.

5. Conclusion

The lunar radiation was observed at 3,000 Mc/s with the 10 meter reflector of the Tokyo Astronomical Observatory, and the following results are obtained by assuming the temperature distribution over the lunar disk as given by equation (1).

1. The maximum temperature on the equator is 390°K (±50°), and higher than the Piddington’s value at 24,000 Mc/s.
2. The equatorial minimum temperature is about 240°K (±50°).
3. The periodic temperature variation on the lunar equator is about $\pm 75^\circ$K.

4. The maximum temperature is observed a few days after the optical full moon.

5. The beam width of the antenna is comparable with the moon's diameter and the exact form of the temperature distribution, such as given by equation (1), is difficult to be deduced from our observation.

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References