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An Implementation Method of Electrical Reference Standards for Permanent Lunar Bases

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Abstract

This paper describes a solution of establishing voltage and resistance standards for permanent lunar bases. Solid-state voltage standards and alloy standard resistors are used as lunar reference standards. Their stability depends on solar irradiance through photoelectric measurement system. Electrical reference standards are important for permanent lunar based, but the drift cannot be observed during long space life, traditional tracing method is invalid on the moon, and solar irradiation is a nature light source with good stability, so it can significantly improve long time stability for electrical reference standard by using photoelectric measurement system as reference.

1. Introduction

What kinds of technology could guarantee measurement accuracy at future permanent lunar bases? Metrology for space is becoming more and more concern[1]. Almost all measurements finally transfer to voltage measuring to analog to digital converter, and the digital signals are easy to store, process and transport. So the electrical metrology standards are the sources of all kinds of measurement. But the measurement on the moon could not be traced to higher level standards just as on earth, and building complex Josephson Array Voltage or Quantum-Hall Resistance primary standards is extremely difficult. Solid-state voltage standards and standard resistors can be used as the reference for short period in space ships and space shuttles. Its annual stability is about several 10^{-6}, and only depends on the stability and temperature control. Once the temperature loses control, its voltage value and resistance value will shift away and even the temperatures go back, the value irreversible changes will be happen. More badly, the changes and drifts cannot be fixed or calibrated on the lunar bases.

On earth, electrical standard in laboratory developed maturely. Voltage can be reproduce by solid-state voltage standard or standard cells, based on zener diode or saturated liquid electrolyte. Resistance is reproduce by resistors made up of low temperature coefficient alloy. They are stable and the quantities are possible to trace to natural standards defined by the physical constants. The electrical standards provide significant supports for various scientific researches, it is also important for permanent lunar bases. Therefore, the paper researches methods for establishing electrical standard for lunar bases, attempt to provide an operational technology solution.

2. Electrical reference standards for lunar bases

The electrical reference standards on the moon are to maintain and realize the electrical units, include voltage, current and resistance, and keep consistent with the earth. Perhaps, the main factors lead difference between the lunar reference standard to earth's are:

1) About 300 K temperature changes on the moon surface during a lunar day, approximate 29.5 earth days.
2) High-energy cosmic rays may damage circuit.
3) Lower gravity, about 1/6 of earth's.
4) Vibration during the rocket launch may change the standards structure.

These factors above should be seriously considered when designing a lunar standard. The semi-conductor solid state voltage standards and the alloy standard resistors are feasible for lunar electrical reference standards combining with the current space technologies. Thermal control is possible to meet temperature demands of electrical standard in spaceship, the anti-radiation technique can shield cosmic rays, centrifuges can verify changes at different gravities, and structure optimization can improve anti-vibration performance. But when we send standards on the moon, how to verify the stability and correct them after unknown change?

3. Solar irradiation reference

For estimate the stability of electrical reference standard on the moon, more stable physical quantity need to be selected as reference.

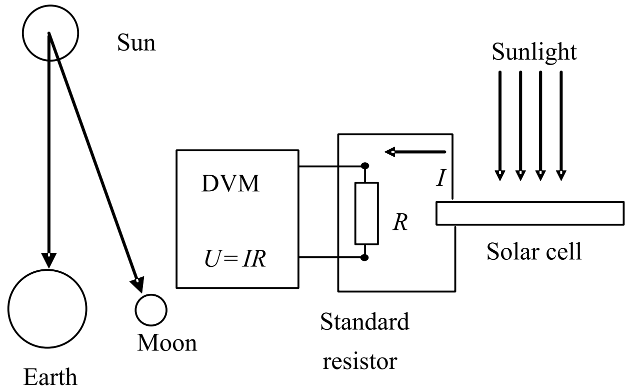

Figure 1. The photoelectric measurement system diagram

The solar irradiation could be a reference, because the distances between sun to earth or moon can be calculate by orbits, and the irradiation stability can improved through correction by earth observation data. If we build two same photoelectric measurement systems separately on the moon and earth, as shown on figure 1, the idea can be realized.

The photoelectric measurement system is made up of solar cell, resistor and voltage meter, the solar cell's short current I (A) and the sunlight irradiance W (W/m^2) have good linear relation.

$$I = KW \quad (1).$$

$$U = RI = RKW \quad (2).$$

Note: K----transfer factor of solar cells.

We measure the irradiance every month at a certain relative position between the moon and earth. Suppose the near two data observed on the earth at this time and last time express as V_{E1}, and V_{E2}. At same time, on the moon the two data express as V_{L1}, and V_{L2}.

1) If $V_{E1}= V_{E2}$, and $V_{L1}= V_{L2}$, it indicates no change happen.

2) If $V_{E1}\neq V_{E2}$, and $V_{L1}\neq V_{L2}$, it indicates the solar irradiance, the distance between the moon and earth, or the lunar standard change.

If the change of the moon-earth distance is too small to ignore, compared with the sun-earth distance, the change of solar irradiance is equal between moon to earth. So the photoelectric measurement system measured at earth W_E and measured at moon W_L have the equal relative change.

$$\frac{dW_E}{W_E} = \frac{dW_L}{W_L} \quad (3).$$

More likely the reason is the solar irradiance change caused by sunspots, magnetic storm, or etc., the distance changes might be another possible reason. But the relative changes observed between moon to earth are equal. The equation (3) is the basic principle. If we measure the irradiance relative change on the earth, the true relative change on the moon can be calculated by the equation. The principle bases on natural phenomena the difference of relative location between moon and earth can be ignored every month.

According to equation (1), (2) and (3), the expectant voltage on moon V'_{L2} can be calculated as:

$$V'_{L2} = \frac{V_{E2} - V_{E1}}{V_{E1}} V_{L1} + V_{L1} \quad (4).$$

If we measure the voltage V_{L2} at lunar bases is not same as the expectant value V'_{L2}, ($V'_{L2}\neq V_{L2}$), it demonstrates the reference standard on the lunar bases have some change during the twice observation. The relative deviation express as:

$$\delta = \frac{V'_{L2} - V_{L2}}{V_{L2}} \times 100\% \quad (5).$$

The solar irradiance is the reference quantity measured on lunar bases and earth station, and the measurement on earth station is able to trace to metrology standard, and the quantity on the lunar bases can trace to the solid-state voltage reference on the moon. By this way, the electrical quantity on lunar is able to trace to earth standards. It is a typical application of remote calibration, and improving the reliability of lunar measurement systems.

4. Error factors analysis

The photoelectric measurement system is very important, and made up of solar cell, standard resistor and voltage meter. Obviously, the solar cells on lunar and earth should have same transfer factor and the long term drift. The transfer factor K of solar cell depends on semi-conductor material characteristics, spectrum response, temperature, irradiation area, irradiation angle and attenuation.

Solar cells are used to sense the deviation of solar irradiance this time and last time, not care the irradiance absolute value. Although there are difference spectrums between moon surface and ground, the solar spectrums are constantly, the deviation of solar irradiance can be ensured by part of spectrum. So the factor K could be keep stability by follow considerations:

1) Reducing solar irradiance time, only one measurement per month to reduce work time, after work in a short time, change to standby mode, and prevent cosmic radiation.

2) Control temperature, irradiance area and angle, keep stable conditions.

3) The irradiance attenuation on lunar base depends on protection glasses. Keep clean and choose anti-radiation material.

4) The irradiance attenuation on earth depends on weather and the path of sun light through atmosphere. The ground station, as shown in figure 1, cannot be vertical to sunlight at different seasons. The earth photoelectric measurement system need to work on aircraft or satellite, it can continue record the change of solar irradiance.

5) To obtain the information about solar irradiance changes is the main task of earth measurement system. It can refer to the information from weather service and astronomical observatory. At this field they have a lot of observation data [2][3][4]. In climate observation, solar irradiance reflected from lunar surface is consider as a reference for satellite remote sensing [5]. According to some reports [6], the stability of solar irradiance reflected from lunar surface to ground is about several 10^{-7}.

5. Conclusion

The electrical reference standards on the lunar bases are the technical foundation to ensure accuracy measurement. The solid-state voltage standard and alloy standard resistor with special design and strict process can be reference standards on lunar bases. Regard the solar irradiance as common reference. The standards stability can be estimate by common solar irradiance, with earth observed correction. The implementation method can realize the remote calibration for the lunar reference by remote communication. The lunar electrical reference standards ensure the reliable measurement systems for a long period.

6. Acknowledgements

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7. References

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