VARIATION OF DIELECTRIC CONSTANT AND BRIGHTNESS TEMPERATURE WITH RESPECT TO PERCENTAGE OF WATER ICE CONTENT. OPN Calla[1],Shubhra Mathur[1,2], Kishan Lal Gadri[1,3] and Monika Jangid[1,4] International Center for Radio Science, Ranoji Ka Baag, Nayapura, Mandore, Jodhpur Rajasthan India. [1]opnc06@gmail.com; [2] shubhra.icrs@gmail.com; [3]kishan.icrs@gmail.com; [4]monika.jangid.icrs@gmail.com

Abstract: The terrestrial Analogue of Lunar Soil (TALS) which has similar mineralogy to lunar soil has been tested for its electrical properties at lunar temperatures. This TALS are mixed with water ice at low temperatures. The electrical properties that includes Dielectric Constant and loss tangent has been measured at -196˚C for variable percentage of water ice. This study of TALS mixed with distilled water at -196˚C will provide the possible quantification of water ice on Lunar Permanently Shadowed Region (PSR) in deep inside the craters on the lunar poles. In this paper the variability of Dielectric Constant (DC) with different percentage of water ice are presented. These measured Dielectric constant values are then compared with available values in literature. It is observed that Litchenecker Model is giving the very close result to the lab measured values of dielectric constant at International Centre for Radio Science (ICRS), Jodhpur, India. The brightness temperature (BT) is simulated using two layer regolith model with help of the measured DC values. It can be concluded that in absence of water ice the DC value of lunar regolith varies from 4-4.2 and as we increase the % of water ice it goes up to 10.34 at 30% of water ice.

Introduction: Water ice on lunar surface is a critical resource for future space exploration. Water may have been delivered to the Moon over geological timescales by the regular bombardment of water-bearing comets, asteroids and meteoroids. From the scientific research done it can be concluded that the water ice of few centimeters is buried by a thin regolith at cold traps in Permanently Shadowed Region (PSR) of lunar poles.

The study of Lunar Soil needs the actual sample of Lunar Soil that has been obtained by different Apollo Mission. It is not possible, so the recourse is taken from orbitec. Here for the measurement orbitec-JSC1A samples was used, having grain size of 1mm. Earlier these TALS were tested to calculate the DC at different frequencies, at different densities with different temperatures. Then DC were normalized to density were reported [1] after comparing them with Apollo samples given in literature.

In this paper, the measurement of Dielectric Constant (DC) of TALS by varying the percentage of water ice is carried out at ICRS Laboratory. The DC of the TALS mixed with water were measured at -196˚C for variable percentage of water ice. These measurements have been carried out in Earth's atmospheric condition. Our main focus is to study the effect of water ice content on the complex dielectric constant of a lunar simulant.

The wave guide cell[2,3] method has been used for measurement of Dielectric Constant at 2.38 GHz. This frequency is chosen because this is the operating frequency of Mini-SAR and Mini-RF hybrid polarimetric radars onboard Chandrayaan-1 and LRO respectively.

Sample Preparation: For measurements, distill water is used so that no other terrestrial minerals contaminate the TALS. This distill water is mixed with TALS at different percentages by weight. The percentage is varied from 0% to 30% at the step of 5%. This mixture is placed in a container having a solution of LN_2. The boiling point of LN_2 is -196˚C

Method of measuring DC: The waveguide cell method is used for measuring the Dielectric Constant of TALS mixed with distill water at-196˚C. Here, Two-point method [1] of waveguide cell method is used to measure the complex dielectric constant of terrestrial analogue of the lunar soil sample. The methodology of the DC measurements is briefly described in the figure 1.

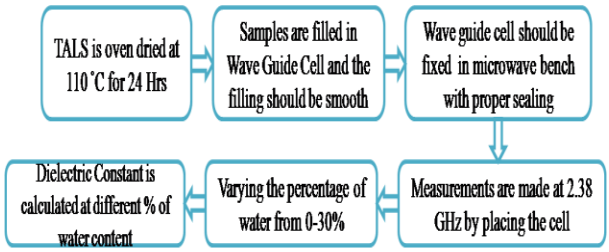

Figure 1: The methodology adopted for DC Measurement

For measuring DC, TALS mixed with distill water which is placed in the shorted waveguide. These measurements are done at -196°C using Liquid nitrogen (LN_2). The waveguide cell is placed in the cold chamber containing LN_2 which lowers the temperature of the terrestrial analogue of lunar soil down to -196˚C. Minima positions are noted with and without sample using the standing wave ratio (SWR) meter.

This shift in minima and standing wave ratio is used for calculating ε′ and ε″. After noting down the shift in minima and standing wave ratio the percentage of water is varied from 0-30% and the readings are noted down according to the variation in the percentage. This process is continued till the lunar soil saturates. During calculation we came to know that Lunar Soil saturates at 30% after this it does not have the capacity to absorb more water and a thin layer of the water can be seen over the lunar soil when we try to add more water into the lunar soil.

Simulation of BT: For simulating BT the two layer regolith model is used which is reported in[4]. In addition to this, there are various mixing model available in the literature to calculate the Effective Dielectric Constant by varying the % of volumetric water ice with the % of regolith content. The various models which have been analyzed is given in [5]

Results and Discussion: Table 1 illustrates the dielectric constant of TALS mixed with pure water at different percentages from 0% to 30%, Dielectric Constant using different mixing models and simulated BT using the Lab measured DC values.

Table 1. Illustrate the measured and the calculated DC by varying the % of water ice. The simulated BT has also shown in the table.

% of Water Ice	Lab Measured DC Values		Model 1	Model 2	Model 3	Model 4	Model 5	Brightness Temperature
	ε′	ε″	ε	ε	ε	ε	ε	BT_K
0	4.2	0.069	4.1	4.1	3.17	4.1	0.93	70.62
5	4.82	0.091	4.9	4.15	3.21	4.6	0.87	69.24
10	5.79	0.106	5.8	4.2	3.25	5.38	0.82	68.71
15	6.63	0.135	7.01	4.26	3.29	6.25	0.77	67.43
20	7.54	0.179	8.34	4.31	3.34	7.34	0.72	65.81
25	8.93	0.24	9.89	4.37	3.38	8.75	0.68	64.26
30	10.34	0.287	11.74	4.42	3.42	10.61	0.63	63.51

These results are unique because no data of DC with different % of water have been reported in the literature. The graph has been plotted relating the DC (Storage and Loss factor), BT and % water ice in figure 2. The DC values increases with increasing the % of water content at -196°C. These measurements are done at one frequency and they are reported for the scientific community for their information and use.

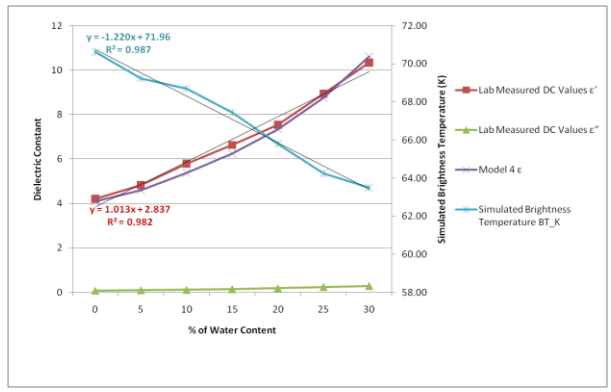

Figure 2: Illustrates the variation in Dielectric Constant , Brightness Temperature along with the % water ice

The corresponding simulated brightness temperature is also decreasing with % of water ice. The variation of DC and BT values of TALS mixed with water ice has lot of importance in the research of lunar craters that are permanently shadowed and there is possibility of the presence of water ice in those PSR region and it shows a direction for the quantification of presence of total water ice present on the moon.

Conclusion: In this paper we have measured DC and simulated its corresponding BT using two layer regolith model. It can be concluded that at in absence of water ice the DC value of lunar regolith is varies from 4-4.2 and as there is an increase in % of water ice it goes up to 10.34 for 30% of water ice. Similarly its corresponding simulated BT decreases so for a particular value of BT we can say about a % of water ice on lunar surface. Our result has also been validated with available models. Litchenecker Model is best fitted to our lab measurements.

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