**STUDY OF SHACKLETON CRATER : INTEGRATION OF MONOSTATIC AND BISTATIC OBSERVATION FROM MINI-RF &ARECIBO.** OPN Calla[1], Shubhra Mathur[2], Monika Jangid[3] International Center for Radio Science, Ranoji Ka Baag, Nayapura, Mandore, Jodhpur Rajasthan India [1]opnc06@gmail, [2]shubhra.icrs@gmail.com, [3]monika.jangid.icrs@gmail.com

**Introduction:** Regions of permanent shadow near the poles of the Moon are thought to contain volatiles such as water ice[1]. In order to know the scattering behavior of ice volatiles, bistatic radar measurements of the lunar poles have been conducted by Mini-RF and Arecibo. These bistatic datasets at non zero phase angle will help in understanding the relation between scattering mechanism and phase angle for detecting presence of water ice. It can also be used for studying the composition and structure of pyroclastic deposits, impact ejecta and melts, and the lunar regolith[2].

Analysis of Shackleton crater has been carried out in the paper. Shackleton crater[3] is an impact located within the South Pole-Aitken basin. Its interior receives almost no direct sunlight and remain in the permanent shadowed region[4] thus a potential site for ice volatiles. But the previous researches and Earth-based radar mapping have yielded conflicting interpretations about the existence of ice volatiles in this crater whether it is due to ice volatiles or rough surface. It had classified the crater as anomalous crater and bistatic study of crater using CPR and Phase behavior had been performed. Authors have tried to relate bistatic and monostatic observations on the basis of CPR , phase angle and also related it with scattering parameters like Degree of polarization and relative phase to understand the target properties. Also same sense and opposite sense parameters have been analysed. This analysis include the comparison of CPR values using both datasets and also the calculation of derived stokes parameters like degree of polarization, relative LH-LV phase.

**Analysis and Discussion:** S-Band datasets of Mini-RF [5](7.4 m/pixel resolution) and bistatic data (100m/pixel) have been used for the analysis.SAR data strips of Shackleton crater taken by Arecibo and Mini-RF is shown in figure1. SAR data provides stokes vector which has been transformed using different conversion techniques. Analysis includes study of derived parameters from stokes vector i.e. CPR, DoP, Delta etc. Derived parameters of stokes have been calculated using Mini-RF datasets.

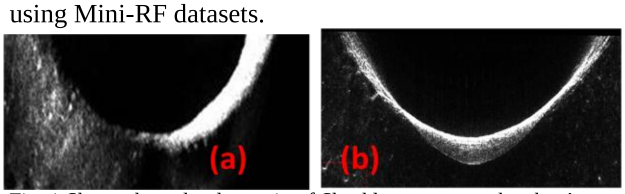


Fig. 1 Shows the radar data strip of Shackleton crater taken by Arecibo (lst_13302_1cp_xiu_82s351_v1) and Mini-RF (lsz_04605_2cd_oku_90s061_v1.img) with an Azimuth angle of 203.9° & 315.04° respectively

*CPR:* Ice has unique radar properties, with high values of the circular polarization ratio(CPR)[6].

$$CPR = SC/OC$$

SC = same polarization as transmitted beam

OC = opposite polarization as transmitted beam

However, high CPR can also be explained by extremely blocky surface causing multiple bounce on a rough surface or double bounce backscatter from corner reflectors regions thus giving high CPR (> 1). High CPR regions are ambiguous. It may be because of roughness or due to presence of water ice. As Ice exhibits the transparent behavior to EM energy and multiply scattered by imperfections and inclusions in the ice, also resulting in high CPR.CPR values have been analyzed for inside and outside region on Shackleton floor. Comparative study of CPR using two datasets have been performed. Inside and outside crater region have been selected taking subset in red and green color as shown in figure 2.

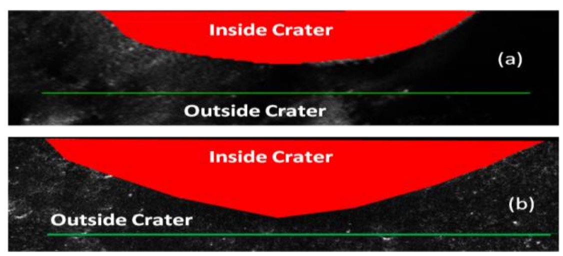


Fig.2 CPR data strips (a) Bistatic (b) monostatic observation with different resolution have been downscaled at ~10m/pixel from its 100m/pixel resolution

From the graph shown in figure 3 it can be seen that elevated or high CPR values are associated with the regions inside the craters and CPR values outside the craters are low for both the datasets. From these results shackleton crater can be considered as anomalous crater. An anomalous crater exhibits elevated CPR only within the interior region of its rim thus Shackleton is an anomalous crater. According to empirical two-component scattering model[7], radar backscatter signal is a composite of specular (OC) and diffuse components (OC). To support the above CPR analysis scatterplot between SC and OC have been plotted as shown in figure 4. Scatterplot has been realized in order to understand the scattering behavior of crater associated with physical characteristics of the lunar surface [7]. It is also supportive with Shackleton crater classification as anomalous crater.

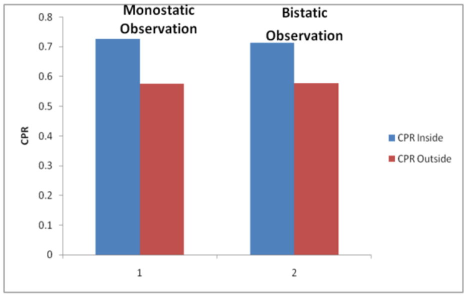


Fig. 3 Illustrates the CPR values for inside and outside region for both Monostatic and Bistatic observation.

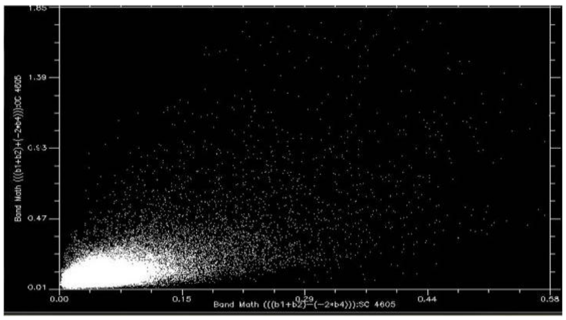

Fig.4 Scatterplots of α vs. γ for the Shackleton polar crater studied using Mini-RF S-band data

*Bistatic Experiment:* Bistatic operation using Arecibo as transmitter and Mini-RF as receiver provide CPR values as well as their relative phase angle. These datasets have been observed at bistatic angle of ~14°-15° using S band frequency. CPR values from Mini-RF and Arecibo have been observed for different β angles. For monostatic observation phase angle ~ 0° and for bistatic observation phase angle ~ 14-15°. For icy volatiles high CPR over β~ 0° should get decrease rapidly with change in bistatic angle for particular incident angle i.e. elevated CPR caused by a rocky surface should be relatively insensitive to the bistatic angle, while high CPR due to ice should be very sensitive to the bistatic angle i.e. CPR values dropping off abruptly at bistatic angles > 1-2°[8].

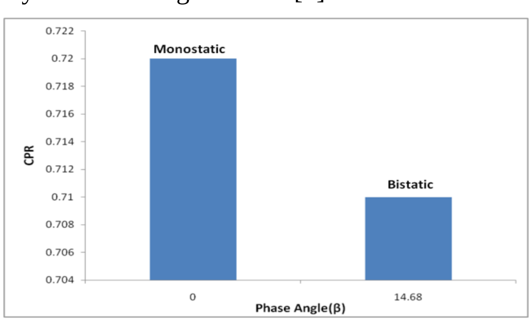


Fig. 5 Shows the average CPR values over the different phase values obtained from monostatic and bistatic observation. CPR values are taken for inside region of shackleton crater.

From the graph in figure 5 it can be seen that there is small change in average CPR values for different phase angle i.e. mono and bi-static. It means the target area is insensitive to the phase angle variation. This suggest the presence of rock deposits on the target under study. Also the backscattered signal over crater floor get polarized low values of degree of polarization (m) i.e. by average of 49.9% for inside crater and for outside region it is calculated as 50.18% exhibiting the volume and double bounce scattering. Distributed values of relative LH-LV phase (δ) have been observed for inside floor of the crater

**Conclusion:** The high CPR values are associated with the regions inside the craters and CPR values outside the craters are low on the crater floor from both the Arecibo and Mini-RF datasets. These CPR signatures are consistent with rocky surface suggesting the crater as anomalous crater. Also from the values of same sense and opposite sense parameters crater can be classified as anomalous crater. Further Study of backscatter mechanism of crater with CPR together with derived stokes parameters like DoP and delta help in understanding the surface constituents in better manner. Knowing scattering behavior of surface will help in distinguishing the high CPR from roughness or ice particles to some extent. From Monostatic and bistatic observation it is found that crater floor is insensitive to the change in phase angle due to the possible effects of rock particles present on crater floor.

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