JOINT ESTIMATION OF HIGH RESOLUTION LUNAR DIELECTRIC CONSTANT AND SURFACE ROUGHNESS USING FULL POLARIMETRIC DATA FROM CHANDRAYAAN-2 DUAL FREQUENCY SAR.

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Introduction: The dielectric constant and surface roughness of lunar regolith is of great significance for understanding the composition and evolution of lunar regolith and the spatial distribution and content of mineral resources [1]. Apollo missions supported a collection of large number of samples of the lunar surface over landing sites and further the density and dielectric constant were measured in the laboratory [2]. These spatial distribution of collected samples are very limited and do not represent large spatio-temporal distribution of actual dielectric constant and surface roughness properties. Lunar orbiter radars are sensitive to dielectric constant and surface roughness of lunar surface [3]. In past, there have been multiple studies for retrieving dielectric constant using lunar orbiter radar data from MiniSAR onboard Chandrayaan-1, MiniRF from LRO [3] and Chandrayaan-2 Dual Frequency SAR [4,5] using hybrid polarimetric data based on either empirical models or decomposition models with various assumptions and constraints like rock-free flat & smooth lunar surface with no concentrations of rocks exposed at the surface where only surface scattering dominates. Previous models are highly constrained and do not account for surface roughness and hence, not used for retrieval of surface roughness. The Dual-Frequency Synthetic Aperture Radar *(*DFSAR*)* aboard India's second lunar mission Chandrayaan-2 is the first fully polarimetric synthetic aperture radar *(*SAR*)* with L & S-band frequencies outside Earth orbit. Detailed architecture of this radar instrument supports multiple polarimetric modes with high resolution [6,7,8] and illustrates the value of dual-frequency quad polarimetry for lunar and planetary applications.

In this paper, we adopted two layer physical radar forward model [9, 10] for simulating radar backscatter and used Chandrayaan-2 DFSAR full polarimetric datasets for the joint inversion of dielectric constant and surface roughness parameters at high resolution. Further, inversion results were validated over Apollo 11 site with the laboratory measurements sampled in the field.

Methodology: Figure-1 shows the flow diagram of methodology adopted in this paper. L-band data from CH-2 DFSAR level-2 calibrated data at 25m pixel spacing [8], acquired over Apollo 11 [11] site was used for processing and further joint inversion of parameters. We adopted global optimization techniques for mathematical inversion of two layer physical radar forward model [9, 10] as non-linear constrained optimization problem. Cost function was defined to minimize and retrieve the unknown parameters (DC, surface RMS height and correlation length) as joint estimation using simulated backscatter using two layer model and CH2 DFSAR L-band data for all three polarimetric channels (HH, HV & VV).

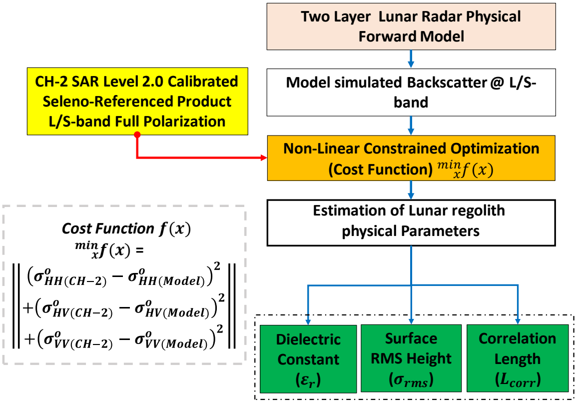

Fig-1: Flow diagram with Inverison Framework

Results and Discussion: Apollo 11 landing site was Mare Tranquillitatis, which was relatively smooth and leveled area. The lunar surface at the landing site consisted of fragmental debris ranging in size from fine particles to blocks about 0.8m wide [11]. Fig-2 shows the CH2 L-band calibrated radar backscatter images from HH, VV, HV polarimetric channels and Local Incidence Angle (LIA), covering Apollo 11 landing

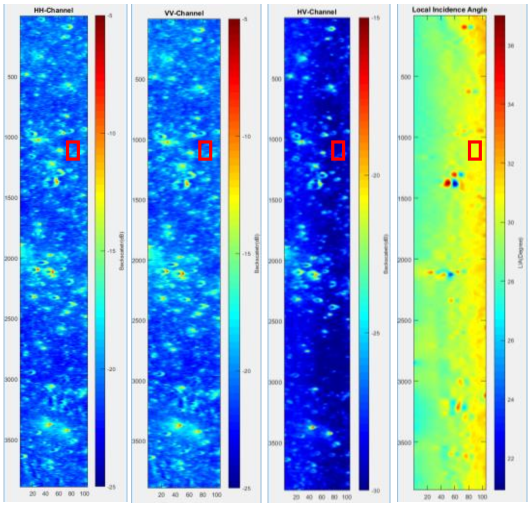

Fig 2: L-band Radar backscatter (i) HH-pol (ii) VV-pol (iii) HV-pol (iv) Local Incidence Angle (LIA) from CH-2 DFSAR data over Apollo 11 site.

site in top right side as red color box. Fig-3 represents the retrieved DC, surface RMS height and correlation length for the CH2 DFSAR scene. Subset (yellow box in fig-4 as zoom portion) of retrieved DC over Apollo 11 site, covering three samples (10017,30; 10065,22; 10084,83) [12] was taken for validation activites. The three samples includes igneous rock (type A), breccia (type C) and regolith fines (type D) with mineral composition, density and other descriptions as per table-1, 2 and 3 [12] with lab based DC measurements of 8.1-9.3, 7.3-8.8 and 3.8 respectively [12]. A 3×3 window is selected in the retrieved DC using CH2 DFSAR image at the position corresponding to the above three sampling point for dielectric constant inversion, and the average value is taken to obtain the final inversion result. Fig-5 shows the histogram of retrieved DC and surface RMS height over zoom portion of Fig-4. We observed that estimated dielectric constants are having very good dynamic range of DC (3-10) over selected samples of Apollo 11 and quite close to the laboratory measurements of above three samples from Apollo 11.

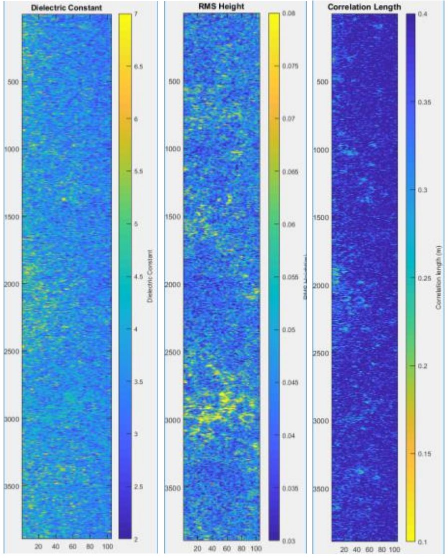

Fig-3: Retrieved Dielectric Constant, RMS height and Correlation Length over full scene of CH2 DFSAR L-band data

Conclusion: We proposed a physical model based inversion framework for joint estimation of lunar dielectric constant and surface roughness parameters using CH2 DFSAR full polarimetric data. Proposed methods has multiple salient features as given below:

- Multivariable nonlinear constrained optimization approach for inversion based on physics based multilayer scattering model.
- Applicable to multiple frequency and SAR Geometry with Full Polarimetric data.
- Wide range of applicability for surface roughness and Dielectric constant over lunar surface.
- Simultaneous retrieval of DC and surface roughness parameters.

This paper presents a new way to jointly estimate the dielectric constant and surface roughness of lunar surface using CH2 DFSAR full polarimetric data, and the effectiveness is verified by inversion of the dielectric constant of Apollo 11 site. This is an initial result, and the performance of the proposed method will be evaluated in the future under more complex terrain conditions and anamalous zones, like permanently shadowed regions over lunar poles.

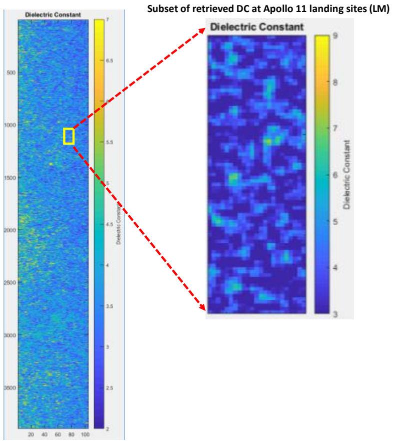

Fig 4: Retrieved DC over Apollo-11 site

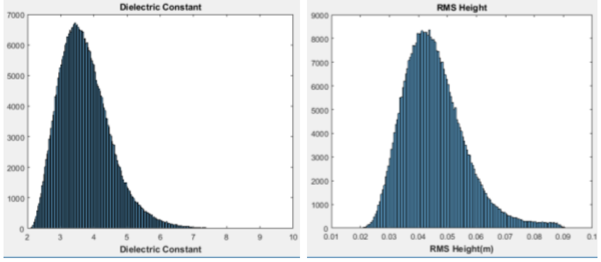

Fig-5: Histogram of retrieved DC (real) and RMS height over Apollo-11 site

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