NEW IMAGING ALGORITHMS DEVELOPED FOR THE HIGH FREQUENCY CHANNEL OF CHANG'E-4 LUNAR PENETRATING RADAR. Jianqing Feng[1,2], Yan Su[1,2], Shun Dai[1,2], Shuguo Xing[1,2], Yuan Xiao[1,2,3]and Chunlai Li[1,2], [1]National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China, (suyan@nao.cas.cn), [2]Key Laboratory of Lunar and Deep Space Exploration, Chinese Academy of Sciences, Beijing 100012, China, [3]University of Chinese Academy of Sciences, Beijing 100049, China.

Introduction: The Chinese *Chang'e-4* (CE-4) mission will be launched in 2018 to explore the lunar far side. To investigate the geological structure of the landing site, the CE-4 rover will carry an instrument named Lunar Penetrating Radar (LPR), which has the same configuration with LPR onboard CE-3 rover [1]. CE-4 LPR is an ultra-wideband pulse radar having two channels. The first channel works (CH1) at 60 MHz and the second channel (CH2) is installed under the bottom of the rover with a center frequency of 500 MHz. The time window of CH2 is 640 ns, during which the LPR would record 2048 samples with an interval of 0.3125 ns. CE-3 LPR has obtained about 2500 non-repetitive traces during *Yutu* rover's ~114m traverse in Mare Imbrium [2]. To improve the interpretation of CE-3 data and assess the detection capability of CE-4 LRPR, a preliminary ground test was carried out last year. As the field test, a 7 m × 3 m × 2.5 m concrete pool with a metallic bottom was constructed and filled with a regolith simulant (CE-5 Lunar Regolith Penetrating Radar was also tested in this field before). Five Granite slates were placed in the regolith simulant, having a size of 60 cm × 60 cm, and their thickness varies from 2.9 cm to 5.1 cm. A metallic ball with a diameter of 25 cm and several basaltic rocks are also buried as targets (Fig. 1).

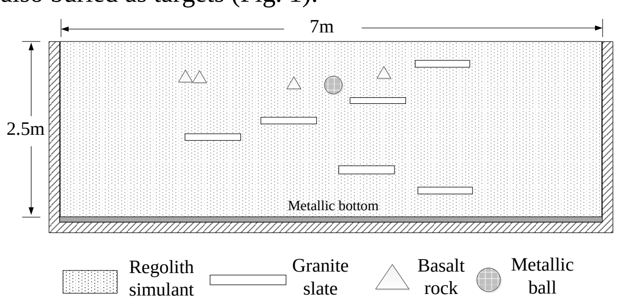

Fig. 1. The actual profile section of the test field.

Data preprocessing: The LPR is a common-offset radar and its data processing includes some regular steps, such as resampling, time-zero correction, bandpass filtering and background removal.

In this test, LPR obtained 413 traces data (Fig. 2) as the rover model moved about 5.6 m within 176 s. All the data were interpolated linearly and resampled according to the rover speed to produce a radargram with equally spaced traces. All traces were then corrected to a common time-zero position, so that vacuum/regolith wavelet first arrival times could be the same across the traces. The first negative peak of each trace was used as the correction. Bandpass filtering is then applied to remove artificial or system noise and improve the visual quality of the data. As strong antenna–ground coupling and shallow near-surface layers cause significant reverberation in the signal that masks later signals, after filtering, the data were processed with a background removal (Fig. 3).

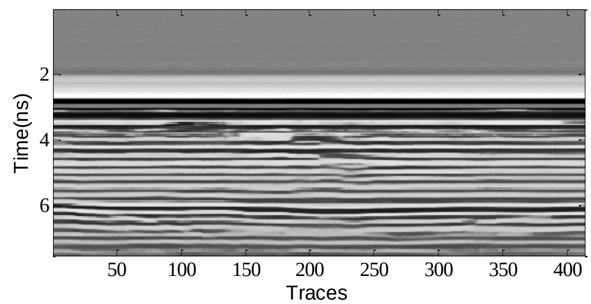

Fig. 2. Radargram of the CH2 raw data detected by CE-4 LPR in the test.

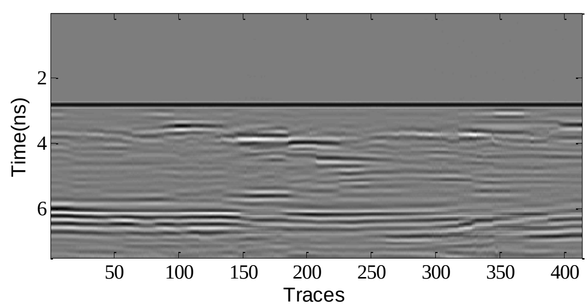

Fig. 3. Radargram of CH2 test data after preprocessing

Conventional method: At first we utilize diffraction stack migration (or back projection algorithm) for the LPR imaging. diffraction stack migration is straightforward, quite flexible and can be easily applied to different array configurations. In this method, the observed reflection is moved from the data-acquisition position back to its true spatial location by propagating each collected time-domain trace backward in reverse time [3]. Integrating the backward propagated signals of all traces within the radar aperture completes the calculation of the diffraction stack for the migrated area [4].

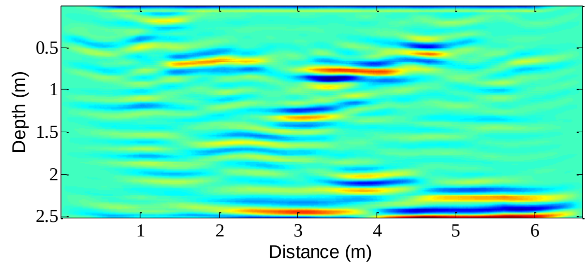

Fig. 4. Migration results by traditional algorithms

However, due to the multiple oscillations of the reflection, these objects' profiles in the migrated image are dispersed, poorly focused, and hard to distinguish from clutter and noise (Fig. 4).

Developed algorithms: we propose to use the cross-correlation sum to replace the simple amplitude summation in the conventional migration equation. Additionally, the Hilbert transformed data is used for the accumulation.

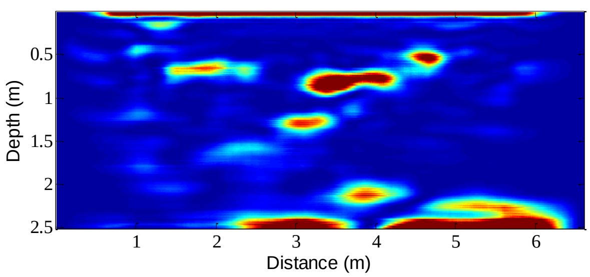

Fig. 5. Migration results by proposed algorithms

The new migration result is shown in Fig. 5. The air/regolith interface and metallic bottom have the strongest reflections, and they are imaged clearly. All the granite slates and metallic balls are accurately positioned, although the diffraction characteristic of the EM wave obscures their precise physical sizes and shapes. Compared with the traditional migration result, the modified migration method reduces the ringing effect, concentrates the reflective energy, makes objects more distinct, and positions the targets more accurately.

Conclusions: A new imaging method based on modified back projection migration is developed for the CE-4 LPR in the ground test. It successfully revealed the structure of the regolith simulant in the test field. This method provides a good reference for data processing and interpretation in the future.

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References:

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