THE RIMFAX GPR INSTRUMENT DEVELOPMENT FOR THE MARS 2020 ROVER MISSION.

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Introduction: The Radar Imager for Mars' subsurface eXperiment (RIMFAX) ground penetrating radar (GPR) experiment for the Mars 2020 Rover will add a new dimension to the rover's toolset by providing the capability to image the shallow subsurface beneath the rover. Radar waves can be transmitted through the air and will penetrate the surface of Mars with minimal interference with rover activities. A GPR instrument can provide subsurface imaging capabilities at sufficient depth, resolution, and timing to be of operational value to the rover mission, while also providing valuable geologic context. A GPR on the Chinese Lunar rover Chang'E-3 successfully penetrated several meters into the lunar subsurface [1]. The WISDOM GPR is planned on the ExoMars mission to be launched in 2020 [2].

2. Scientific Objectives: The principal goals of the RIMFAX investigation are to image subsurface structure and to provide information regarding subsurface composition.

RIMFAX will allow the rover science team to quickly assess the extent and depths of possible buried layers and their stratigraphic relationship to nearby outcrops. RIMFAX will provide a unique view of the stratigraphic section and cross-cutting relations, and thus a window into the geological and environmental history of Mars. Depending on the geologic setting, RIMFAX has the potential to detect a wide range of subsurface geologic features and can provide valuable information regarding the past surface exposure history of sedimentary rock layers.

Depending on materials, RIMFAX will image the subsurface stratigraphy to depths of more than 10 meters with vertical resolutions < 20 cm and a horizontal sampling distance of 10 cm along the rover track. The data provided by RIMFAX will aid the Mars 2020 rover in its mission to explore the ancient habitability of its field area, and in the selection of scientifically compelling samples for caching and eventual sample return.

3. The Radar System: The RIMFAX radar system consist of an electronics box mounted in the rear left tower of the rover. The electronics box is in a thermally controlled area. The RIMFAX antenna is externally mounted underneath the RTG on the back of the rover and has no thermal control. Fig. 1 illustrates where the different radar parts are mounted on the rover body.

The Frequency Modulated Continuous Wave (FMCW) signal is gated so that a single antenna will be used both as a transmitter and receiver antenna. The gating is basically switching the transmitted signal on and off [3]. When the transmitter is off the receiver is switched on and will receive the reflected signal. The radar transmits a frequency sweep starting at 150 MHz up to a maximum of 1200 MHz depending on operation mode. The radar can switch to a calibration cable and measure the reflection from the end of the cable, which is used to monitor the instrument performance and calibrate the radar response.

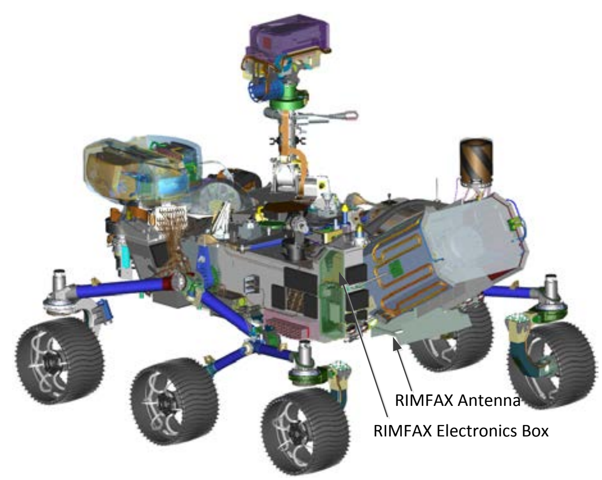

Fig 1. The RIMFAX Electronics box is mounted in the rear left tower and the antenna is externally mounted underneath the RTG on the back of the rover. (Illustration courtesy of NASA/Caltech/JPL).

3. Operation on Mars: The RIMFAX radar will collect data when the rover is either driving or stationary. The radar receiver has a limited instantaneous dynamic range for each sounding. To capture the reflection from the surface and deeper attenuated layers at the same time is not possible. The radar sounding is therefore split into three different modes, which together can capture the full surface and subsurface dynamic range.

- **Surface Mode** where the reflections from the antenna and surface is within the receiver dynamic range window.

- **Shallow Mode** where the antenna reflection is removed by gating and the surface reflection and shallow reflectors are within the receiver dynamic range window.

- **Deep Mode** where the antenna, surface reflection and shallow reflectors are removed from the receiver dynamic range window by gating.

All three modes will be collected every 10 cm along the rover path. Every sounding from the Surface Mode is expected to be downlinked back to Earth. Both the Shallow Mode and the Deep Mode will be collected with an instrumented depth range that is deeper than the expected penetration depth. Data for the Shallow and Deep modes can be both stacked and clipped in range while onboard as to tactically meet, when strictly necessary, operational constraints imposed on downlink volume.

The radar may also collect data while the rover is stationary at a given time interval between each sounding. A sounding can, for example, be taken every hour over a Sol, thereby measuring the effects of thermal changes in the subsurface over the diurnal cycle.

A longer integration mode will be used while the rover is stationary. In this mode the soundings are integrated in the rover allowing bit growth and thereby higher dynamic range in the receiver. A long integration sounding will be collected every time the rover stops for a time period in the order of a several minutes.

The radar also has two passive modes where the received noise is captured either on the calibration cable to measure the radar internal noise, or on the antenna to measure external noise.

3. Field test: A prototype version of the antenna that is very close to the expected Flight Model was tested on Svalbard in April 2016. The antenna was mounted on a glass fiber pole sticking out on the back of a snow mobile sled, see Fig. 2. The field test was mainly an instrument test to verify the antenna performance. An earlier prototype version of the RIMFAX radar was hooked up to the antenna. The radar was programmed to emulate the different operation modes. Fig. 3 shows a profile using the surface mode where the antenna and surface reflection are captured within the radar receiver. A background removal is used to remove the strong stationary reflections from the antenna. The radar profile shows the surface reflection from the air/ice interface together with a shallow reflection from the ice/ground interface. The radar was tested on several poly-thermal glaciers in the area.

Fig 2. Prototype version of the RIMFAX antenna during field test on Svalbard in 2016.

References:

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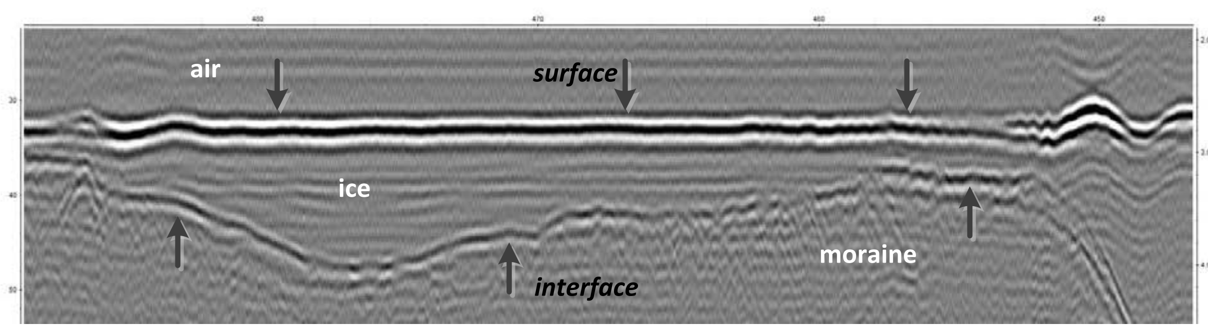

Fig 3. Radar profile using the Surface Mode. The length of the profile is around 40 meters and the depth scale is about 1.5 meters below the surface reflection.