THE GROUND PENETRATING RADAR RIMFAX ON THE MARS 2020 MISSION.

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1. 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. There are several possible geophysical techniques that are routinely employed to image the shallow subsurface. Most of them require direct contact with the ground and are therefore not appropriate for a rover mission such as Mars 2020. Radar waves can, however, be launched in air and can be used to penetrate the surface of Mars with minimal interference with rover activities. A GPR instrument can provide subsurface imaging capabilities at sufficient depth, resolution, and timeliness to be of operational value to the rover mission, while also providing valuable geologic context.

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

RIMFAX will provide the rover and its science team with the capability 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 history and associated environmental history. Depending on the geologic setting, RIMFAX has the potential to detect a wide range of subsurface geologic features. RIMFAX subsurface images can provide valuable information regarding the past surface exposure history of sedimentary rock layers.

Due to planetary protection requirements, the Mars 2020 rover will not be targeted to a site where near-surface ground ice or liquid water are likely to be present within the first few meters of the surface [1]. However, the existence of deeply buried layers of ice, liquid water, or brines that are not in equilibrium with present climatic conditions cannot be excluded by presently available observations. RIMFAX's potential to provide new information regarding this possibility is substantial.

Depending on materials, RIMFAX will image the subsurface stratigraphy to maximum depths of 10 to 500 meters, with vertical resolutions of 5 to 20 cm, with a horizontal sampling distance of 5 to 20 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 select a set of promising samples for caching and eventual sample return.

3. Mars Radar Experiments: Radar is an outstanding remote sensing technique for Mars because it can easily penetrate the ubiquitous surface dust and regolith layers. Both Earth-based radar imaging [2] and spacecraft radars have revealed buried terrains such as lava flows, buried channels, and polar ice cap stratigraphy.

In particular, the SHARAD (Shallow Radar) instrument on MRO [3] has revealed details of the interior structure and the composition of the polar ice caps [4, 5], detected interfaces beneath plains sediment layers [6], enabled measurements of lava flow dielectric properties [7], and allowed tomographic reconstructions of buried fluvial channels [8].

The lower frequency Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument on Mars Express [9], penetrates through up to 3.7 km of polar cap ice and reflects from the basal interface [10].

The WISDOM GPR experiment [11] on ESA's ExoMars Rover will be designed to explore the first ~3 meters of the subsurface and will support near surface rover drilling operations to depths of 2 meters.

The RIMFAX is designed to have a frequency range between the orbital radars SHARAD and MARSIS and the WISDOM GPR so as to get deeper penetration than WISDOM and higher resolution than SHARAD and MARSIS.

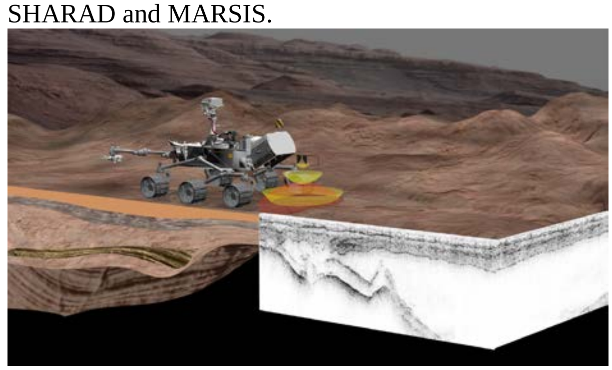

Fig 1 – Illustration of how RIMFAX will operate on Mars.

4. The Radar System: Commercial Ground Penetrating Radar (GPR) systems that are being used on Earth normally use time domain impulse signals. The receivers in these systems are very often time repetitive sampling receivers [12, 13]. It has been shown that this waveform is not optimal regarding power consumption and dynamic range [14, 15]. We have therefore chosen a Frequency Modulated Continuous Wave (FMCW) waveform for the RIMFAX radar. In an FMCW radar the Intermediate Frequency (IF) signal or baseband signal is low pass filtered before being sampled. This filter effectively removes deeper reflectors and makes an ambiguity free range interval.

The FMCW waveform 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. When the transmitter is off the receiver is switched on and will receive the reflected signal. The radar range response with the gating will be a convolution between the transmitted square wave and the receiver square wave [14] resulting in a triangular response funtion. This response will function as a range gain in depth. A typical gating frequency for a deep looking radar mode will be 100 kHz.

A schematic of the radar is given in Fig. 2. The FMCW-waveform is made in an FPGA and clocked out to a DAC to give the analog signal. The signal from the DAC is multiplied and filtered to give the transmitted sweep. The sweep is gated in a switch before amplified and fed to the antenna via the antenna switch. The received signal is amplified and gated in a switch before mixed with the transmitted signal. The IF signal after the mixer is low pass filter and digitized into the FPGA.

The operating frequency of the radar is determined by the antenna. Target low frequency cutoff for the RIMFAX antenna is 150 MHz. The high frequency cutoff will be determined by the shape and size of the antenna, and its position on the rover, subject to the results of an ongoing rover accommodation study.

More details on the radar system and results from a prototype radar system will be given in the presentation.

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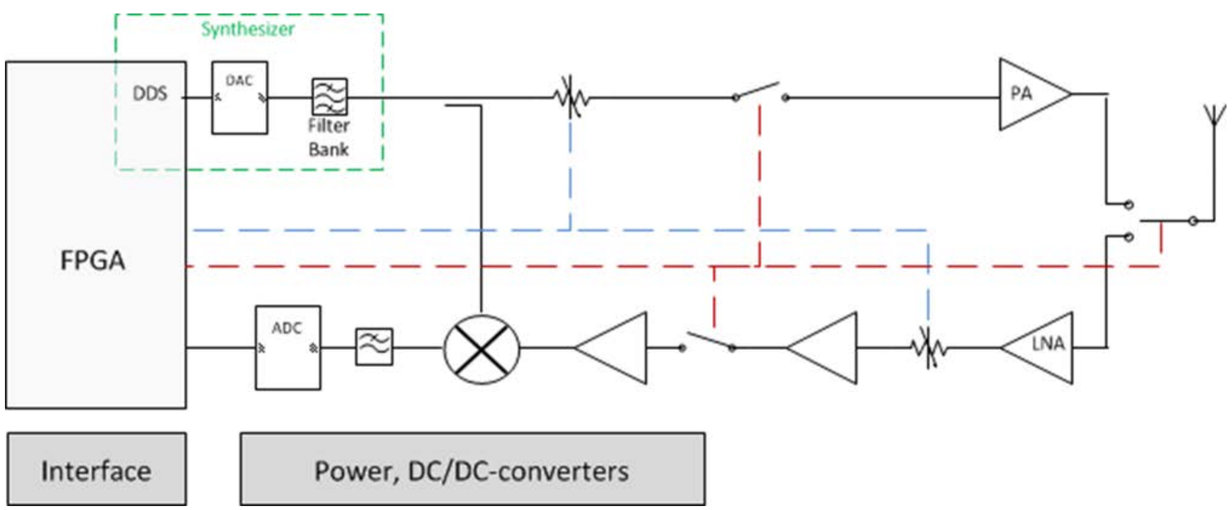

Fig.2 Schematic diagram of the RIMFAX radar.