RIMFAX RADAR Antenna prototype using Mars perseverance vehicle

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Abstract: The RIMFAX radar is a Gated-FMCW Ground Penetrating Radar to be on aboard the NASA Mars 2020 rover mission. The radar is operating from 150 – 1200 MHz and is using an Ultra Wideband Bow-Tie Slot antenna at 60 cm above the ground surface. Depending on ground conditions the radar has the ability to penetrate to more than 10 meters depth. The first results from glacier measurements are promising.

IndexTerms - —GPR; Gated-FMCW, Radar Imaging; Mars; Mars 2020

I. INTRODUCTION

The Radar Imager for Mars' Subsurface Experiment –
RIMFAX is a Ground Penetrating Radar selected to be on the MARS 2020 NASA rover. RIMFAX will add a new dimension to the rover's toolset by providing the capability to image the shallow subsurface beneath the rover. A significant challenge in Mars rover missions has been the lack of access to vertical stratigraphy. The principal goals of the RIMFAX investigation are to image subsurface structure, and to provide information regarding subsurface composition. RIMFAX has the potential to provide a view of the stratigraphic section and a window into the geological history and associated environmental history. This article will give an overview of the scientific objectives, instrument development and show results from the first field test.

II. 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 gives a unique view of the stratigraphic section and cross-cutting relations, and thus a window into the geological history and associated environmental history. RIMFAX subsurface profiles can provide valuable information regarding the past surface exposure history of sedimentary rock layers. For example GPR can reveal thickness variations in subsurface layers, bedding discontinuities, evidence of impacts, and aeolian or fluvial erosional features.

Depending on materials, RIMFAX will image the subsurface stratigraphy to more than 10 meter depth, with vertical resolutions better than 30 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 select a set of promising samples for caching and eventual sample return.

III. 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 and spacecraft radars have revealed buried terrains such as lava flows, buried channels, and polar ice cap stratigraphy.

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.

IV. THE RADAR SYSTEM

The RIMFAX radar is Gated-FMCW radar operating over the frequency band 150 – 1200 MHz's. The radar consists basically of an electronics box connected to an Ultra Wideband antenna.

The frequency generation is made by a Direct Digital Synthesis (DDS) inside an FPGA and converted by an external Digital to Analog Converter (DAC). Due to clock frequency limitations of space qualified FPGA and DAC chips the final bandwidth is made up by multiplication and subsequent filtering of the frequency generated by the DAC. Typical sweep time over the full bandwidth is between 1 – 20 ms depending on operating mode. The frequency band is built up by three separate sweeps: 150 – 300 MHz, 300 – 600 MHz and 600 – 1200 MHz respectively.

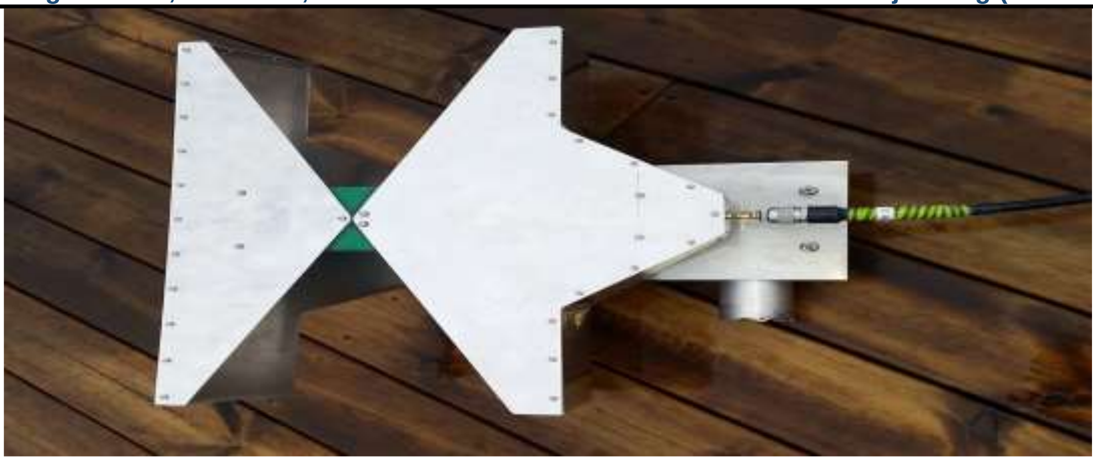

Fig. The RIMFAX Antenna is an Ultra Wideband Bow-

Tie Slot Antenna.

DefineThe antenna is an Ultra Wideband Bow-Tie Slot antenna shown in Fig. 1. The antenna is partly open on the back due to accommodation issues on the rover. The antenna has a transmission line matching and is fed by coaxial cable on the side of the antenna. The antenna shown in Fig. 1 is an early prototype and was used for the field tests reported here.

The RIMFAX electronics box is located in one of the rover towers on the left side of the rover and the installation is illustrated in Fig.2.

The antenna is located at the rear of the rover between the RTG and the rover chassis see Fig. 3.

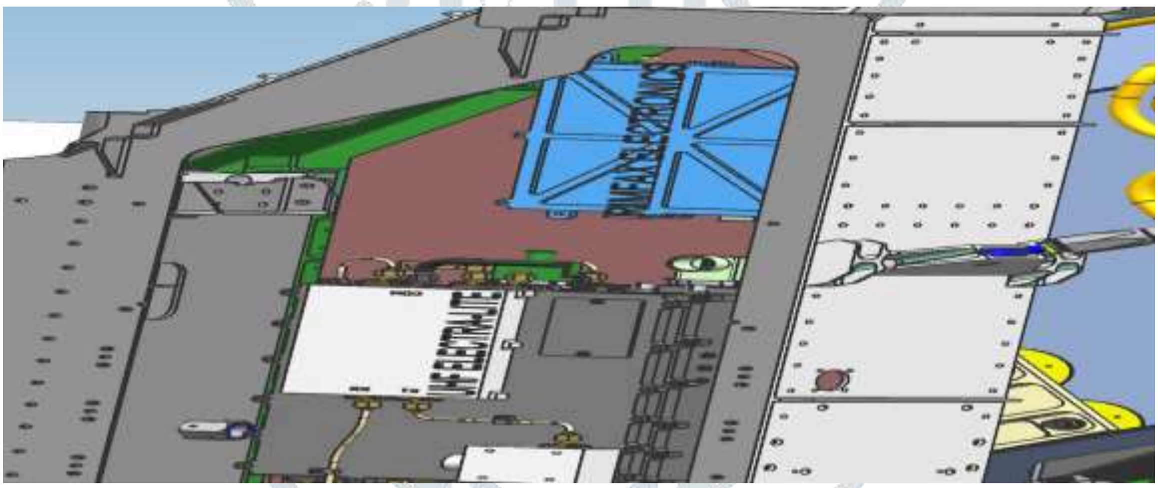

Fig. 2 The RIMFAX Electronics Box is located in left rear tower of the Mars 2020 Rover (Illustration Courtesy NASA/JPL-Caltech).

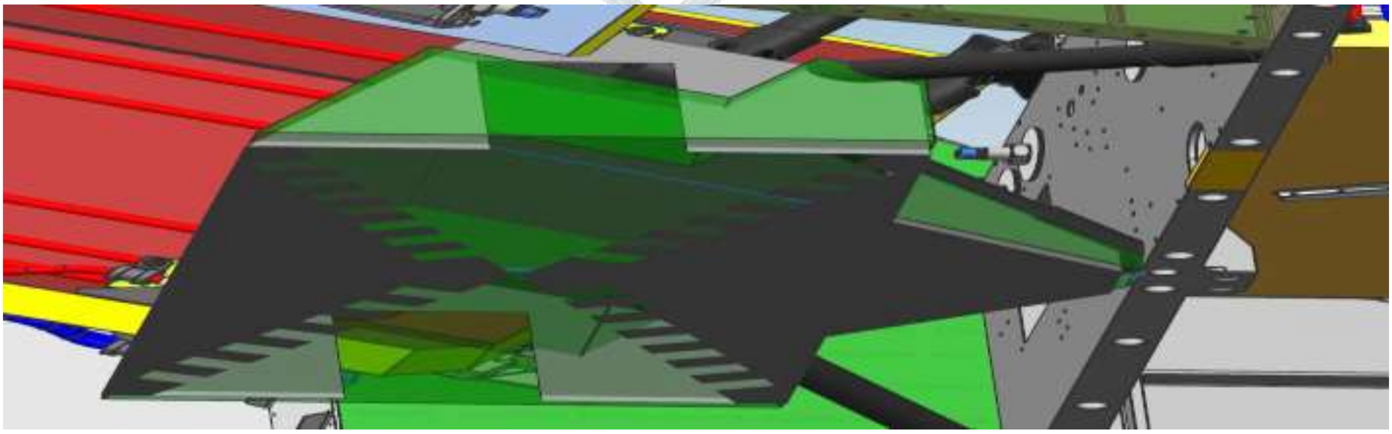

Fig. 3 The RIMFAX Antenna is located under the RTG and between the RTG and the Rover body at the rear of the Rover (Illustration Courtesy NASA/JPL-Caltech).

V. Operation

RIMFAX is planned to be operating while the rover is moving. Integration time for one radar sounding will be 100 ms. One sounding will be an integration over several sweeps. The sampling distance between each sounding will be 10 cm.

RIMFAX will measure the surface reflection and use that for a first estimate of the surface permittivity and thereby the radar propagation velocity in the near surface. The surface reflection needs to be measured by the receiver without compression of the signal. This means that the radar needs to have reduced receiver gain or reduced transmitting power when measuring the surface reflection and effectively reducing the System Dynamic Range of the radar system. The RIMFAX receiver has a limited dynamic range and RIMFAX therefore operates by collecting two soundings with different mode settings for every 10 cm.

The first shallow mode will have a gating setting so that the surface reflection is in the receive window. The second mode will have a gating effectively removing the surface and other strong reflectors. When the strong reflectors are removed from the receiver signal, the radar can have a higher receiver gain and use higher transmitter power

VI. FIRST FIELD TEST

An early version of the radar was field tested with the prototype antenna shown in Fig. 1. The field test was conducted on Midtre Lovenbreen on Svalbard, Norway in the end of April 2015. Midtre Lovenbreen is a polythermal glacier with a cold surface layer and a temperate layer at the bottom in parts of the glacier.

The radar and antenna were mounted on a sled pulled by a snowmobile, see Fig 4. The positioning was done by recording the GPS location. The radar was controlled by a laptop computer that also stored the data during data collection. The integration time for each sounding was 15 ms and the travel speed while collecting the data was around 20 km/hour.

Fig. 4 The photo shows the antenna mounted on a sled at approximately 60 cm above the snow surface.

Fig. 4 shows a 120 meter long radar profile at the lower part of the glacier. These data were processed by applying a Blackman-Harris window function, zero padding and taking an inverse Fourier transform to obtain the profile. No further processing was done such as background removal. The lower part of the glacier is cold and frozen at the bottom.

The operating frequency is from 150 – 1200 MHz so the center frequency of this profile is around 650 MHz. Fig. 5 shows the magnitude of the data. A zoomed in version of the scattering from the bottom of the glacier is shown in Fig 8. Fig. 6 displays the real part of the signal so that both the magnitude and the phase are shown.

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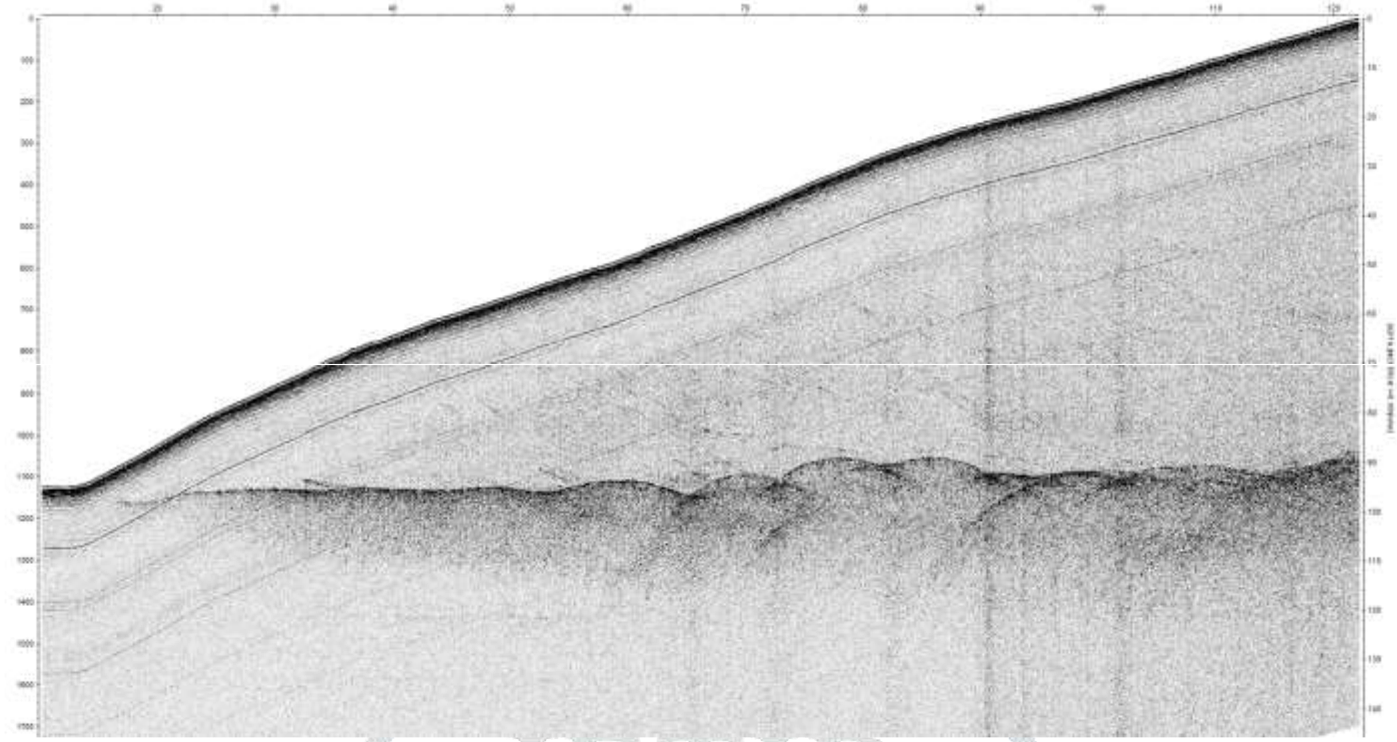

Fig. 5 The figure shows a 120 m long radar profile along the Glacier Midtre Lovenbreen on Svalbard, Norway.

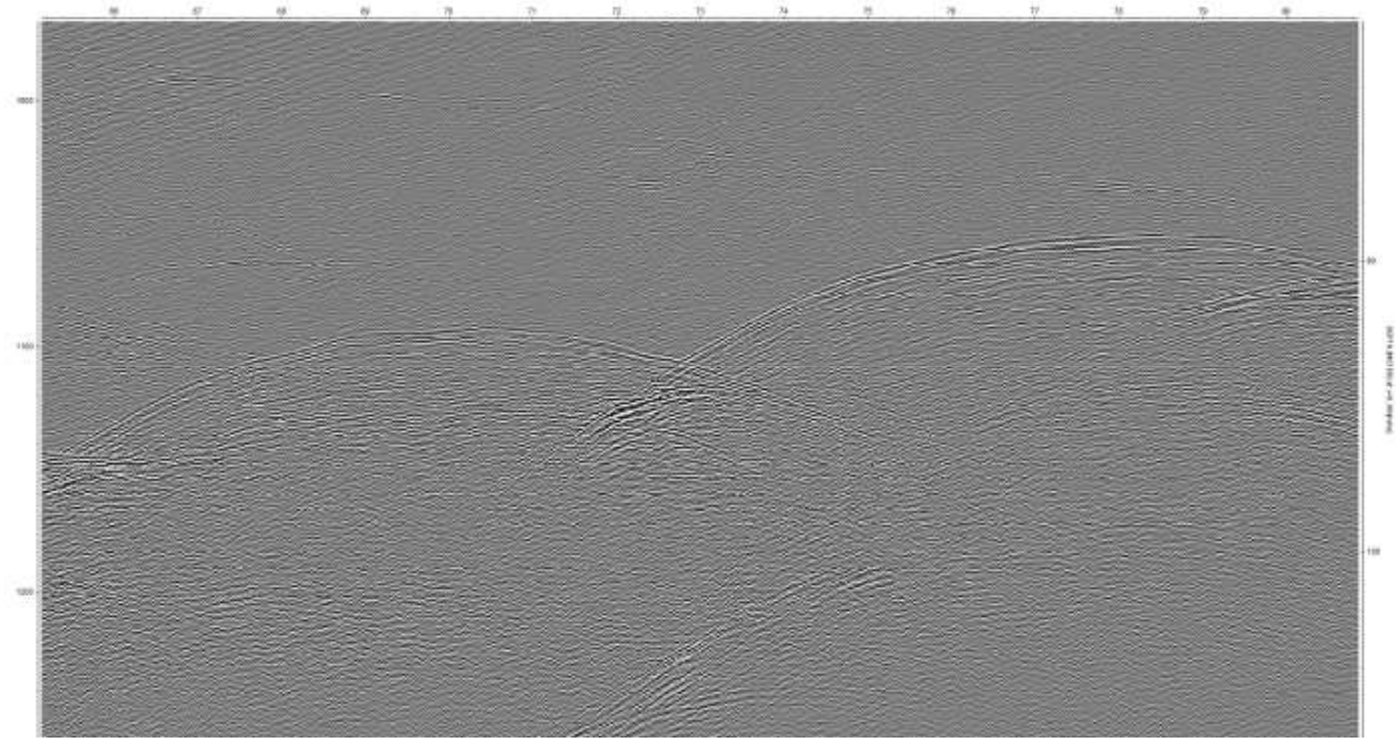

Fig. 6 The figure gives a zoomed in version of Fig. 5 where scattering hyperbolas from the rough glacier bottom is seen.

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