UltraWide Band (UWB) Radar for the High-resolution Imaging of Martian Regolith for Human Exploration.
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We propose to develop an Ultra-WideBand (UWB) radar that would enable a rover or an astronaut on the surface of Mars to survey their surroundings and readily identify water ice, hydrate minerals, or volatiles buried at Mars shallow subsurface < 1m. NASA's Phoenix mission confirmed the presence of subsurface water ice at a depth < 10 cm, evidence that the soil had a wetter and warmer environment in the recent past. The depth and water ice thickness suggest that water may have been present as thin films on the surface. This implies that ice and hydrate minerals would be in the form of minuscule amount on Mars where surface erosion is intense due to wind: any exposed water ice will sublimate following exposure. Ground penetrating radar capable of resolving a few cm thick interfaces would be an excellent scientific instrument to non-invasively characterize such shallow subsurface. The proposed radar would have a bandwidth of 9 GHz capable of achieving a vertical resolution of 1 cm in ice while operating at a few meters above Mars surface.

Various UWV radars have been built to image objects or moving targets not detectable with optical sensors. However, spaceborne UWB radar with centimeter resolutions has not yet been developed. The proposed radar consists of UWB digital and RF electronics (see Fig. 1). It uses a very short pulse of <200 ps to achieve a bandwidth of up to 10 GHz. The short pulse is first amplified by a UWB amplifier and then radiated by a UWB antenna (T). Returned echoes are collected by another UWB antenna (R) before being amplified and digitized. Having two separate antennas minimizes a cross talk and avoids the need of a fast (~ ns) switch between transmission and receiving circuitry. We have identified commercial UWB amplifier and antenna, and characterized their performance at 1-10 GHz. As shown in Fig. 2, we have also calibrated a cross talk and overall beam gain at 1-10 GHz.

The key enabling technology in the RF electronics is a UWB Transmit/Receive (T/R) matching network that allows an efficient power delivery among transmitter amplifier, antennas, and receiver amplifier. We have performed a feasibility study of matching network design working over an entire band of 1-10 GHz using an Advanced Design System (ADS) simulation tool. Our preliminary study has shown that it is possible to build the T/R matching network that could produce a uniform system gain over the entire band, as shown in Fig. 3.

The digital electronics consists of pulse generator, timing circuitry, FGPA controller, and UWB analog-to-digital converter (ADC) with on-board memory. The speed of ADC needs to be faster than 20 GHz to meet the Nyquist sampling requirement. With the advent of a 8-bit ADC running at up to 56 GHz, it is now possible to build UWB digital electronics that utilizes a low-power light-weight direct sampling scheme without relying on a mixer for frequency downconversion. This would simplify the design of UWB digital electronic components. By coherently adding multiple bursts using on-board memory on the ADC, we can significantly reduce I/O traffics between digital controller and ADC. This will allow us to use relatively slow digital control electronics components.

Due to a close proximity to Martian surface, the radar needs a radiated power level of just 1 mWatt to achieve a surface signal-to-noise ratio (SNR) level of 10 dB. On-board coherent pre-summing would further increase SNR, necessary to penetrate tens of cm to meter. The instrument could be miniaturized to be a hand-held device or mounted on a mobile platform like Mars rover.

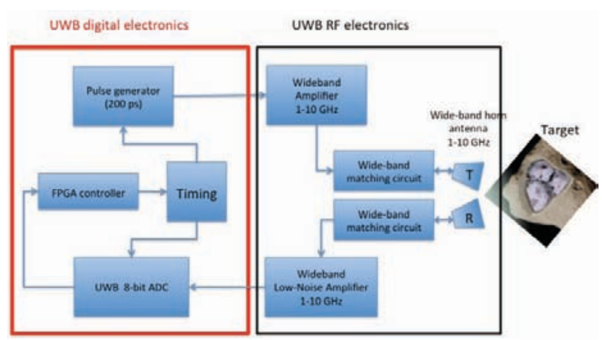

Fig. 1: UWB radar block diagram

Fig. 2: UWB antenna cross talk and gain calibration at 1-10 GHz

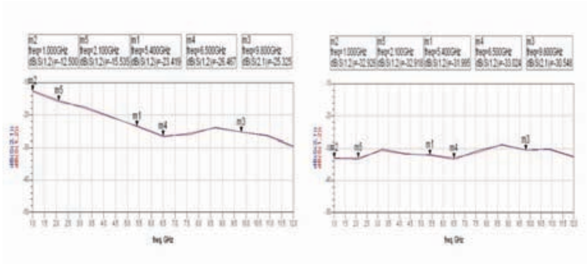

Fig. 3: System gain performance without (Left) and with (Right) R/T matching network