Development of subsurface radar for future Mars, the Moon, and asteroid explorations

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Specification and design of radar for subsurface structure measurements in future Mars, the Moon, and asteroid exploration missions have been investigated. In Mars Aqueous-environment and space Climate Orbiter (MACO), measurements of mars subsurface ices in mars low and mid-latitude region (suggested by recurring slope lineae (RSL)) by subsurface radar sounder are planned in order to clarify the contribution of subsurface water cycle to mars climate. This observation also enables us to select out candidate sites for future landing explorations. In JAXA's lunar ice prospector mission by an international collaboration between Japan and India in early 2020s, measurements of three-dimensional distribution of ice below the lunar surface by ground penetrating radar (GPR) installed on the rover are proposed. Design of this GPR could be a baseline of designs of future space-born GPR. Based on the observations of bulk density and boulder size on the surface by Hayabusa, 25143 Itokawa is suggested to be a rubble-pile asteroid. If the size and shape of the rocks inside the asteroid are determined by radar sounder, we can discuss the formation process of the asteroid based on them.
For MACO mission, we are proposing a radar sounder installed on the orbiter transmitting chirp pulse in a frequency range of 50-150 MHz with a peak power of 10 W in order to detect ice within a depth of several 100 meters at a vertical resolution of 1.5 m. For JAXA's lunar ice prospector mission, we are proposing a ground penetrating radar installed on the rover transmitting chirp pulse in a frequency range of 0.5-3 GHz with a peak power of 15 dBm in order to detect ice within a depth of several meters at a vertical resolution of 6 cm. For exploration of asteroid internal structures, the radar sounder for MACO will be applicable also. If we can plan bistatic radar sounding by using radar, transponder, and reflector installed on another orbiter or lander in addition, we can determine not only the subsurface structure of permittivity contrast but also the absolute value of permittivity for discussion of porosity and composition of the internal rock lumps.
In design of the radars for space missions, we can not select parts freely. We have to use limited rad-hard semiconductor parts. In 50-150 MHz, there are selectable D/A converter (DAC) and A/D converter (ADC). So we can select the method using DAC and ADC: Transmitting and reference signals are generated by DAC, and receiver output is sampled by ADC. On the other hand, in 0.5-3 GHz, there are not selectable DAC and ADC. So, we are planning to use VCO for generation of transmitting and reference signals. We are now developing BBM of transmitter and receiver considering parts selection and design for space-born instruments. In late 2020, we are planning performance tests with BBM by measuring soil simulant.
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