Geophysical Research Abstracts, Vol. 7, 05757, 2005
SRef-ID: 1607-7962/gra/EGU05-A-05757

New results from the Magellan bistatic radar experiment: A prototype for Venus surface studies with VeRa

M. Kreslavsky (1,2), P. Ford (3), G. Pettengill (3) and J. Head (1)

(1) Department of Geological Sciences, Brown University, Providence, RI, USA (2) Astronomical Institute, Kharkov National University, Kharkov, Ukraine (3) Center for Space Research, Massachusetts Institute of Technology, Cambridge, MA, USA (misha@mare.geo.brown.edu)

Introduction. Bistatic radar experiment is a part of Venus Radio Science experiment (VeRa) onboard Venus Express. In this experiment, the incident signal from a spacecraft-borne transmitter is directed to the specular point on a planet, and the signal scattered by the surface is received on the Earth. At microwave frequencies typical planetary surfaces scatter electromagnetic waves quasi-specularly, which means that the mirror-like reflection component dominates the scattered signal. In this case, the polarization state of the received echo depends only on the electromagnetic properties (dielectric permittivity and magnetic permeability) of the surface material (according to Fresnel's equations), thus providing unambiguous constraints on these parameters.

Several bistatic radar observations of the Venus surface were carried out by the Magellan spacecraft. Analysis of observations performed on June 5, 1994 showed that the surface material at high elevation in Maxwell Montes has a moderately high electric conductivity [Pettengill et al., 1996]. Bistatic observations were also performed on November 9, 1993 [Simpson et al., 1994]. Our analysis of these results [Kreslavsky et al., 2005] can be considered as a prototype study for future investigations with VeRa.

Data processing and preliminary results. November 1993 observations were carried out during three consecutive Magellan orbits. Incidence angles varied in a narrow range from 78˚ to 81˚, which is particularly favorable for interpreting the results since echo polarization at these angles is very sensitive to the electromagnetic properties of the surface. The S-band probing signal was linearly polarized at 45˚ to the scattering plane. The scattered signal was received with a pair of right- and left-circularly polarized coherent DSN receivers (L and R channels). Processing of the received signals (see [Kreslavsky et al., 2005] for details) gives echo intensity, its circular and linear polarization degrees and linear polarization angle along the specular point tracks. An important part of the data reduction process is a cross-calibration of the ground system sensitivity in R and L channels; this calibration was derived from observations of the direct signal from the spacecraft through a sidelobe of the spacecraft antenna.

The *total echo intensity* shows excellent correlation between orbits, which indicates that it is controlled by the surface properties. There is generally an anticorrelation between roughness and echo intensity; very rough tesserae give almost no measurable echo; the strongest echoes come from very smooth areas; many local roughness contrasts coincide with changes in echo intensity. Quantitatively, however, the correlation between roughness and echo intensity is not very high. This implies that the bistatic echo intensity is not sensitive to the same roughness scale as that of the slope derived from the radar altimeter data. Thus, bistatic-radar-derived roughness parameters does not duplicate the Magellan radar altimeter data and may be of interest for geological interpretations.

The *total polarization degree* of the echo is very close to unity for all terrains, except the roughest tesserae, where we do not detect any pronounced echo. This independently confirms that the scattering is quasi-specular and we can expect that echo polarization is well described by the Fresnel equations. The echo is mostly linearly polarized.

The *linear polarization angle* shows spurious systematic differences between the adjacent passes and spurious systematic trends along the passes. We are currently working on ways of removing these effects. Despite them, the along-track variations of the polarization angle correlate very well between adjacent passes, suggesting that these variations reflect true variations of surface dielectric permittivity. There is a correspondence between local variations of the linear polarization angle and geological features seen at the radar images.

The degree of *circular polarization* is small and displays a spurious trend apparently caused by a drift of the sensitivities in the R and L channels. There is only one well-expressed deflection of the circular polarization degree from the trend line. Unfortunately, only one orbit passed over this region, and we cannot confirm that this is a real phenomenon. The observed increase of 15% in circular polarization degree would imply extreme electromagnetic losses in the surface material. This possibly anomalous area contains a wide variety of geomorphic features, but it is geologically unique due to the presence of vast dune fields resolved in the Magellan radar images [Greeley et al., 1992].

Further analysis is in progress. We are working to remove the drifts in cross-calibration of the R and L channels. This will improve the absolute accuracy of the derived polarization state, and we will be able to estimate the dielectric permittivity along the tracks. A comparison with reflectivity derived from the Magellan radar altimeter data can be used to identify layers of surficial deposits, and a comparison with emissivity from Magellan radiometric measurements can be used to look for magnetic materials on the surface [Starukhina and Kreslavsky, 2004].

Implications for VeRa. The Magellan results show that bistatic radar data indeed are informative for the Venus surface science: variations of the surface electromagnetic properties are detectable by the method. The difference between Magellan bistatic experiments and VeRa is that on Venus Express the probing signal is circularly polarized and hence the cross-calibration of the R and L receivers with the direct spacecraft signal is impossible. Some cross-calibration can be obtained suggesting typical dielectric permittivity (known from the Magellan bistatic experiment and other data) for typical terrains. With this method, accurate absolute measurements of the electromagnetic properties are impossible, however, their variations are still detectable and measurable. Experience with Magellan data shows that it is essential to take data for close places from several orbits.

References.

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