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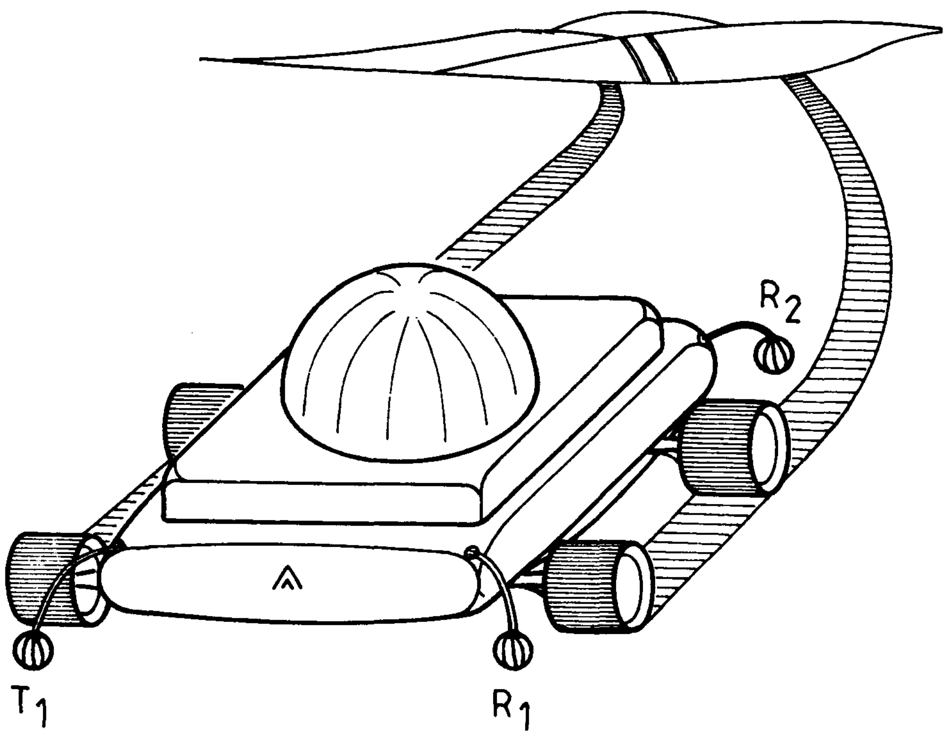
AN INSTRUMENT FOR MEASURING THE COMPLEX PERMITTIVITY OF THE MARTIAN TOP SOIL, R. Grard, Space Science Department - ESA, ESTEC, Noordwijk, The Netherlands.

This instrument will measure the resistivity ρ and the relative dielectric constant ε_r of the Martian top soil along the path of a rover. This aim is achieved by measuring the real and imaginary parts of the complex permittivity $\varepsilon = \varepsilon_r - j\varepsilon_i$, where $\varepsilon_i = (\omega\varepsilon_o\rho)^{-1}$; ε_o is the permittivity of vacuum and ω is a variable angular working frequency. The experimental technique consists in evaluating the mutual, or transfer, impedance of a quadrupolar probe, i.e. in quantifying the influence of the Martian ground upon the electrical coupling of two Hertz dipoles. The horizontal and vertical spatial resolutions are of the order of the length and separation of the dipoles, typically 1-2 metres. The four-electrode method for measuring the ground resistivity on Earth has been first applied by Wenner (1) and Schlumberger (2), but the proposed investigation bears more resemblance with a similar instrument which has been developed for ground surveying at shallow depths, in connection with archaelogical and pedological research (3). A quadrupolar probe will provide essential information about the electric properties of the Martian ground and will contribute usefully to the identification of the soil structure and composition in association with other experimental equipments (camera, infra-red detector, gamma and X-ray spectrometers, chemical analyzers, ground temperature probes). Complex permittivity measurements will reveal small scale anomalies caused by discontinuities in surface material distribution, underlying fractures and cavities, burried boulders, etc.., leading to the selection of soil sampling and drilling locations and to the characterization of the site environments. If a sufficient data base can be collected over the entire lifetime of the rover, it will be possible to draw maps of the electric properties of the terrain and compare them with features derived from topological, geological and thermal surveys. If the rover stands at the same location for a period of at least 1 Martian day (1 sol = 24 h 39 mn) or returns to the same site after a period commensurate with a Martian year (669 sols), diurnal and seasonal variations in the distribution of volatiles may give rise to measurable changes of the local complex permittivity. The detection of obstacles (large boulders) or ground level gradients (small craters) out of the field of view of the camera may also support the autonomy and the safe operation of the vehicle. A quadrupolar probe consists of a transmitting dipole (T_1, T_2) and a receiving dipole (R_1, R_2); an alternating current, I_t, is injected between T_1 and T_2 and a potential difference, V_r, is simultaneously measured between R_1 and R_2. The transfer impedance, $Z = V_r/I_t$, is a function of the dielectric properties of the environment. The probe array can be arranged in an infinite number of ways and a possible configuration is illustrated in the following figure (probe R_1 not visible), where four spheres are mounted at the corners of the vehicle (4). Assuming a square array of side L at a height h above the ground and neglecting the presence of the rover body, it can be shown that the transfer impedance is approximately given by $Z = Z_o\,(0.59 - 2\alpha((1 + x^2)^{-\frac{1}{2}} - (2 + x^2)^{-\frac{1}{2}}))$, where $Z_o = (4\pi j\varepsilon_o L\omega)^{-1}$, $\alpha = (\varepsilon - 1)/(\varepsilon + 1)$ and $x = 2h/L$. The transfer impedance can be rewritten $Z_o \simeq (0.59 - \alpha(0.59 - 0.65\,x^2))$ for $x \ll 1$. The size, geometry and location of the sensors are not critical; in order to minimize the mass, it is proposed to make use of meshed spheres or disks with a diameter of about 10 cm, small compared with the dimensions of the vehicle. The sensors should be mounted as close as possible to the ground (∿15 cm) and as far as possible from the vehicle (∿30 cm); it is absolutely not required that the array be square. The perturbation introduced by the presence of the rover will be taken into account through a preliminary calibration. The sensors are not rigid and the mounting stems are flexible so that any unforeseen contact with ground protrusions cannot affect their shape nor impede the operation of the vehicle. The working frequency is varied in steps from 100 Hz to 3 MHz; the amplitudes of the transmitted current and received voltage are measured and the difference between the phases of the two signals is evaluated for each frequency step. As a bonus, it is possible to monitor in the passive mode, i.e. without any signal applied to the transmitting dipole, the activity of atmospheric VLF electromagnetic phenomena (frequencies less than 10 kHz), by sending the signal collected by the receiving antenna into a filter bank, or a spectrum analyzer. The quadrupolar probe is a sturdy and versatile instrument with relatively modest requirements (2 W, 2 kg).



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