Planet. Space Sci., Vol. 38, No. 7, pp. 951–952, 1990
Printed in Great Britain.

0032-0633/90 \$3.00+0.00
Pergamon Press plc

REPLY TO R. N. SINGH'S COMMENTS ON THE PAPER BY LESCEUX *et al.*

J. M. LESCEUX and J. LEMAIRE*
Institut d'Aeronomie Spatiale de Belgique, 3 Av. Circulaire, B-1180 Brussels, Belgium

and

N. MEYER-VERNET
Observatoire de Paris-Meudon, DESPA, Meudon, France

(*Received in final form 21 March 1990*)

INTRODUCTION

R. N. Singh recognizes that "electric potential waveforms can be generated by (passing) micrometeoroids and recorded by electric dipole antennae aboard spacecraft as proposed by Lesceux *et al.* (1989)" (*sic*). This was indeed the main goal and conclusion of our research paper. Consequently, its main objectives were well received.

Besides that, it is claimed in these comments that "the waveform analysis is based on highly idealized assumptions" (*sic*) and secondly that "the computed waveforms would not yield realistic information of the charged distribution generated by micrometeoroids in space" (*sic*). Although Singh claims that this is "shown" in his comments, no demonstration or any quantitative proof has been proposed in support of his statements and claims. Although Singh "hopes that some of his comments would be helpful in developing further details ..." (*sic*), in this reply we point out that some of his statements are unfortunately incorrect and the others are irrelevant.

Poisson's equation and wave equation

In the first paragraph he claims that "the Poisson's equation does not correctly depict the electric potential distribution generated by a charged micrometeoroid" (*sic*); but Poisson's equation is part of Maxwell's fields equation: $\nabla \mathbf{E} = 4\pi q_t$ where q_t is the total electric charge density including the charges on the surface of the meteoroid as well as the charge distribution in the surrounding plasma. Poisson's equation must in any case be satisfied, even for micrometeoroids in a space plasma. It is surprising, indeed, that he did not realize that his wave equation (4) is precisely equal to Poisson's equation when the electric field $\mathbf{E}$ is replaced by $-\nabla\psi-(1/c)\,\partial\mathbf{A}/\partial t$ with equation (2) to eliminate $\nabla \cdot \mathbf{A}$.

The solution of equation (4) (i.e. Poisson's equation) is the Lienard–Wiechert potential. The expression of the electric potential used by Lesceux *et al.* is the non-relativistic approximation of the Lienard–Wiechert potential (i.e. for $V \ll c$) shielded by the plasma over a distance equal to the Debye length.

As stated in the Introduction of Lesceux *et al.*'s paper, the grain velocity V satisfies $V_{\text{thi}} \ll V \ll V_{\text{the}}$, where V_{thi} and V_{the} are the ion and electron thermal velocity, respectively. Under these conditions, $V_{\text{thi}} \ll \omega/k \ll V_{\text{the}}$ so that (except if the electron temperature is much larger than the ion temperature), the plasma temporal dispersion is negligible and the plasma dielectric function is $\varepsilon(k,\omega) \propto 1+1/k^2L_D^2$ (see Meyer-Vernet and Perche, 1989). Note that, for the parameters considered, the ambient grains themselves do not contribute to ε either. Solving Poisson's equation in Fourier space with this ε yields the potential given by equation (1) of Lesceux *et al.*'s paper.

On the right-hand side of equation (4) in Singh's comments the expressions of "the source term", $f(r,t)$, and of the dielectric constant ε are not specified as they should have been to make his statement less ambiguous. Indeed, either $f(r,t)$ includes the charges of the plasma and $\varepsilon = 1/4\pi$, or $f(r,t)$ represents only the charge density of the grain and Singh's expression of the wave equation is then erroneous since it ignores the plasma spatial dispersion, namely the Debye shielding.

Since, anyway, Singh writes that he is unable "to provide an adequate solution to the problem dealt by Lesceux *et al.*" (*sic*), we do not quite understand what his comment has contributed to, nor what it should have been useful for.

* On leave at the Observatoire de Paris-Meudon, DESPA.

Variation of the grain's charge Q

Singh cautions that the electric charge and therefore "the potential of the grain ... may vary as a function of time and distance from the antennae" (*sic*).

In the environments considered in Lesceux *et al.*'s paper the characteristic relaxation time corresponding to the variation of the grain's charge is of the order of magnitude 1 s or larger: > 1000 ms (see for instance Whipple, 1981). Since this is much larger than the time scale of a few milliseconds over which the variation of $\Delta\psi$ is calculated in our paper (and measured with an antenna), Q can safely be considered as constant. This means that Singh's statement is irrelevant.

The variation of the grain velocity

It is argued in Singh's comments that "the dust grains do not move with a constant velocity ..." (*sic*). To change by 1% the velocity of 10 km s^{-1} of a grain in the relevant time scale of 5 ms requires a force 2000 times larger than the gravitational force at the surface of Earth, or about 10^7 times larger than the electrostatic force between a typical spacecraft (or antenna) charged at a potential of 5 V and a grain with a radius of 5 μm at about the same potential with respect to the plasma. This clearly shows how irrelevant Singh's statement is indeed.

Misprints

Note that Singh's misunderstandings were not related to the misprints that unfortunately remained in the published version of the paper by Lesceux *et al.* We apologize for these misprints and wish to take here the opportunity to correct them:

in equation (3): replace r_1 and r_2 by r_1^2 and r_2^2;
in equations (8) and (11): replace n by m_e;
in equation (12): replace m by m_e.

CONCLUSIONS

Nevertheless, Singh eventually gets to the same conclusion as Lesceux *et al.*, i.e. that "if actual potential waveforms are recorded using electric dipoles, an inversion algorithm can be constructed to derive various parameters of micrometeoroids" (*sic*). We wish to thank Singh for drawing attention to the basic idea of Lesceux *et al.*

Although, initially we had been less optimistic than Singh about the possibility of detecting micrometeoroids using this new method, the comprehensive discussion in the last section of Lesceux *et al.*'s paper indicates that it is quite realistic to envisage the implementation of this new technique as a complementary feature for future plasma wave instruments planned to study the environment of Comets or or Planets, including that of our Earth where more and more artificial debris is added continuously to the natural dust particle environment.

REFERENCES

Lesceux, J. M., Lemaire, J. and Meyer-Vernet, N. (1989) Electric dipole antennae used as micrometeoroid detectors. *Planet. Space Sci.* **37**, 1291.

Meyer-Vernet, N. and Perche, C. (1989) Tool kit for antennae and thermal noise near the plasma frequency. *J. geophys. Res.* **94**, 2405.

Whipple, E. C. (1981) Potentials of surfaces in space. *Rep. Progr. Phys.* **44**, 1197.