PROGRAM PACKAGE FOR THE CALCULATION OF SATELLITE ANTENNA PATTERN CHARACTERISTICS DURING THE OPERATION OF VERNIER ENGINES ON THE BASIS OF EP

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One of the main problems, arising while using electric propulsions (EP) on board the spacecrafts, is connected with meeting the necessary requirements on electromagnetic compatibility with on-board radio systems.

Two aspects of this problem might be studied simultaneously:

- EP self-induced electromagnetic radiation and its influence upon the on-board radioelectonic systems;

- effect of EP generated plasma blobs on the electrophysical properties of self-induced atmosphere of the spacecraft, determining the nature of electromagnetic waves propagation.

While the first problem is studied quite well by conducting a large number of experimental measurements with lists of necessary limiting standards as a result, the second problem requires the fulfillment of both experimental and theoretical studies of particular electrodynamic tasks of electromagnetic waves propagation through non-uniform physical mediums.

Task of investigation of the EP-based thruster operation influence upon the on-board antenna systems characteristics is examined in this paper.

In this case, 3-dimensional task is studied in electodynamic

statement for arbitrary mutual spatial disposition of:

- spacecraft, modeled by absolutely conductive body;

- reflective antenna system, the mathematical model of which is represented by circular equivalent phase plane of currents. This model describes the antenna pattern behavior near the main beam quite well; it is conventional enough for the satellite antennas calculations (see [1] for example);

- EP plasma plume of which is modeled by a non-uniform dielectric body with given law of refraction factor distribution, critical density area being modeled by a metallic body of given geometrical shape.

The resultant 3-directional antenna pattern is determined for the arbitrary mutual geometric disposition of chosen elements using strict electrodynamics methods in view of additional currents, induced in the antenna aperture by the secondary fields induced at the plasma plume and at the spacecraft surface.

Specially developed numerical analogs of the integral equations method were used as investigation methods for electromagnetic waves interaction with the models of spacecraft and plasma plume. Iterative algorithm of sequential diffraction, allowing to minimize the volume of calculations without accuracy loss was used as a basis of calculations in this case.

Program package was developed on the basis of obtained mathematical algorithms for the calculation of 3-dimensional directivity characteristics of on-board antennae as well as of isolines of equal pattern intensities, projected onto the Earth surface in the case of arbitrary spacecraft trajectory.

Developed software-hardware complex allows to solve the following tasks:

a) analysis for the on-board antenna pattern distortions at arbitrary antennae orientation relative to the spacecraft body

and thrusters on the basis of EP;

b) optimization of mutual disposition geometry for antenna systems and EP on the spacecraft surface;

c) calculation and formation of an area of stable communication at the Earth surface and its cyclic variation for arbitrary spacecraft orbits.

Calculation results for the directivity characteristics of reflective antenna, mounted on the spacecraft of cylinder shape are presented in Fig.1 as an example. The plots represent by themselves the normalized patterns for E and H fields correspondingly:

1 - inherent antenna pattern;

2 - system pattern in view of the spacecraft body influence;

3 - system pattern in view of the spacecraft body and EP plume influence.

Fig. 2 shows the corresponding pattern cross-sections in the form of isolines for the case of mutual geometry, presented in Fig.1.

Analysis of results, presented in Fig. 1 and Fig. 2, shows that mutual influence of the spacecraft and plasma plume might cause substantial distortions of antenna patterns, which in some cases may lead to the failure in radio communications with the spacecraft. Application of the developed package allows to take these factors into account beforehand and to optimize the procedure of communication contact with the spacecraft.

REFERENCE

A.R.Cherritte, S.W.Lee, R.Acosta "Shaped Contour Beam Synthesis Using a Single Shaped Reflector and a Single Feed Element". "Antennas and Propagation International Symposium", 1988, p.141.

Antenna

α° – 40.
L – 1.5 m
S – 2. m
D – 3. m

Spacecraft

R – 1. m

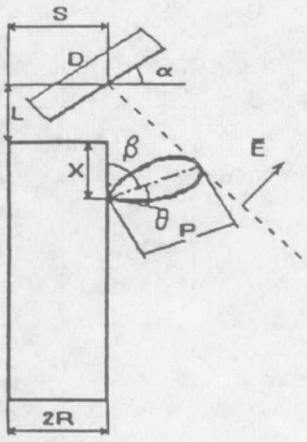
Plasma plume

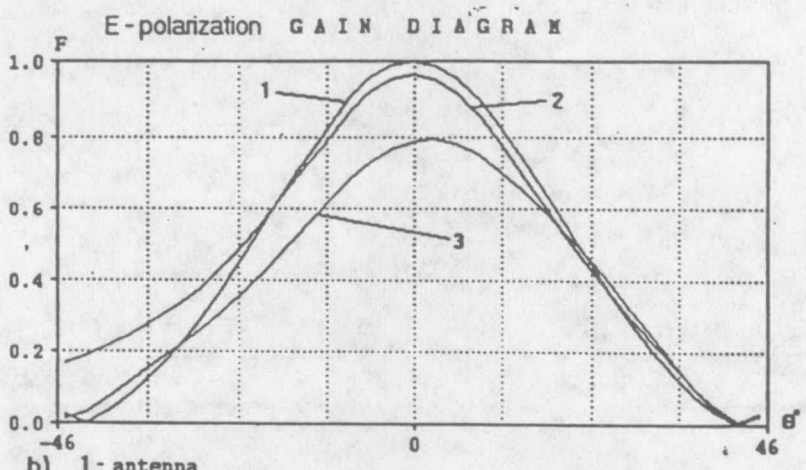
P – 2. m
θ° – 40.
β° – 65.
X – 1.5 m

EM waves

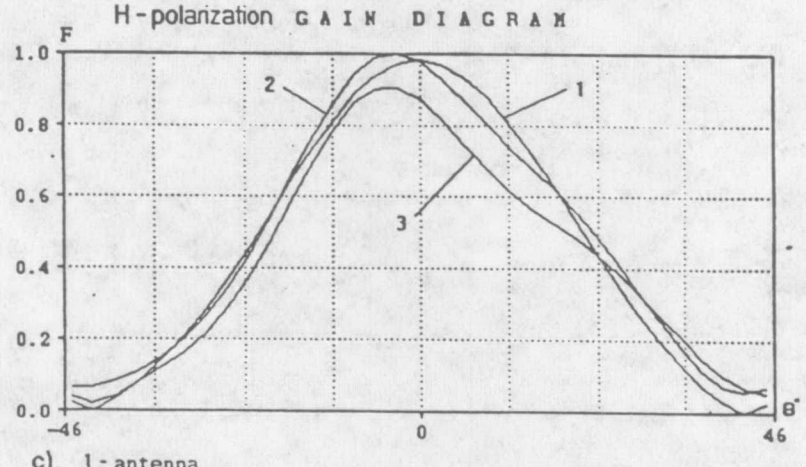
F – 0.18 GHz

a).



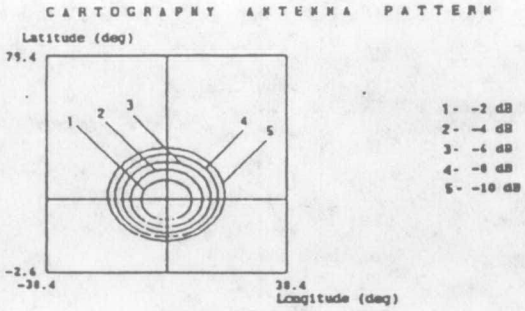


b). 1 - antenna
2 - cylinder
3 - plasma

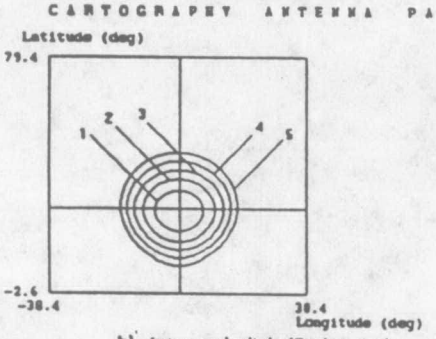


c). 1 - antenna
2 - cylinder
3 - plasma

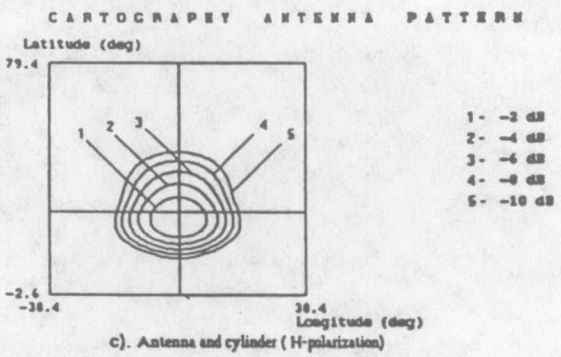
Fig. 1



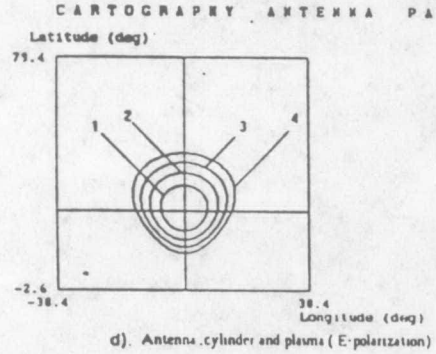
a). Antenna



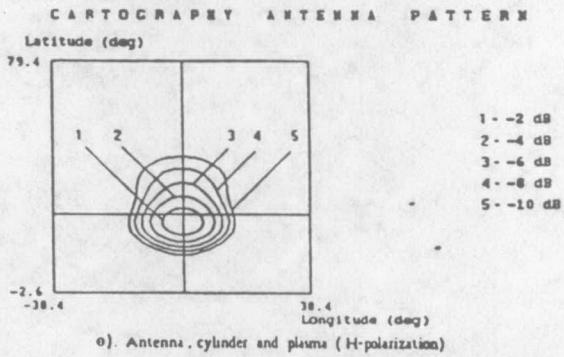
b). Antenna and cylinder (E-polarization)



c). Antenna and cylinder (H-polarization)



d). Antenna .cylinder and plasma (E-polarization)



e). Antenna , cylinder and plasma (H-polarization)

Fig. 2