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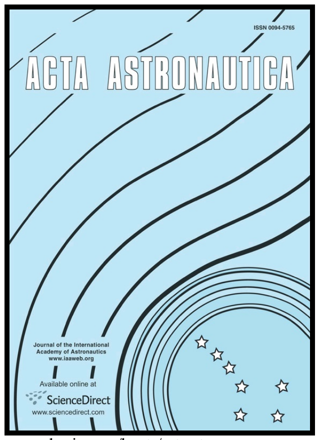

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Electromagnetic absorption properties of spacecraft and space debris

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Abstract
Aim of the work is to present a method to evaluate the electromagnetic absorption properties of spacecraft and space debris. For these objects, the radar detection ability depends mainly on volume, shape, materials type and other electromagnetic reflecting behaviour of spacecraft surface components, such as antennas or thermal blankets, and of metallic components in space debris. The higher the electromagnetic reflection coefficient of such parts, the greater the radar detection possibility. In this research an electromagnetic reverberation chamber is used to measure the absorption cross section (ACS) of four objects which may represent space structure operating components as well as examples of space debris: a small satellite, a composite antenna dish, a Thermal Protection System (TPS) tile and a carbon-based composite missile shell. The ACS mainly depends on geometrical characteristics like apertures, face numbers and bulk porosity, as well as on the type of the material itself. The ACS, which is an electromagnetic measurement, is expressed in squared meters and thus can be compared with the objects geometrical cross section. A small ACS means a quite electromagnetic reflective tendency, which is beneficial for radar observations; on the contrary, high values of ACS indicate a strong absorption of the electromagnetic field, which in turn can result a critical hindering of radar tracking.

Keywords: Absorption Cross Section, Space Debris, Satellite, Antenna, Thermal Protection System, Missile Shell

1. Introduction

Identifying space objects represents a crucial task for nowadays space activities. Radar observations are very important for space object tracking and surveillance. For example, it is well known that stealth satellites are planned to be used in spying mission and that non-operational satellites are sometimes difficult to track, due to the weakness of the reflected electromagnetic signal received by the tracking station. Furthermore, the long-standing problem of the space debris requires to develop ever more reliable detection systems, in order to achieve a suitable level of safe operating conditions. In this work, the absorption cross section (ACS) measurements of a small satellite, a composite antenna reflector, a Thermal Protection System (TPS) tile and a carbon-based composite missile shell are reported. Such objects may represent a standard reference in this context, since they are typical space operating objects/components; on the other hand, in turns, they can be actually considered as examples of short space-life payload objects, bound to increase the space debris population. The electromagnetic characterization was performed by means of a reverberation chamber, which is an environment very well suited for electromagnetic compatibility (EMC) testing and other electromagnetic investigations [1,2]. Future work will concern the possibility to relate the ACS measurements to real radar detection capability as well as to optical observation and detection.

2. Materials and methods

2.1 Reverberation chamber

Basically, a reverberation chamber is a screened room with negligible electromagnetic energy absorption. Due to low absorption, a very high field strength can be achieved with moderate input power. The chamber is a cavity resonator with high quality factor (Q) [3]: the spatial distribution of electrical and magnetic field strengths is thus strongly inhomogeneous (standing waves). To reduce such inhomogeneity, one or more tuners (stirrers) are used. A tuner is a structure with large metallic reflectors that can be moved to different orientations in order to achieve different boundary conditions. The lowest usable frequency (LUF) of a reverberation chamber depends on the size of the chamber and on the tuner design; for example, small chambers have a higher LUF than large chambers. Although permittivity and permeability are intrinsic properties of the materials, the absorption properties of relatively large objects depend also on shape, volume, material type, and on the incoming wave polarization and direction of incidence. In real environment the excitation of any structure exhibits random characteristics, thus evaluating the absorption capability for a particular condition could be meaningless. Therefore, a full characterization of EM absorption properties requires the measurement repetition using several angles of incidence and polarization. Reverberation chamber is in this context an excellent way to excite the absorbing material in a completely random way, thus overcoming the limitation of other