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MULTI-FUNCTIONAL RADIATING STRUCTURES FOR SOLAR SAILING MISSIONS

Abstract

Solar sailing imposes challenging requirements on the spacecraft. The small force exerted on the sail by the sunlight results in a proportionally small acceleration of the spacecraft. A higher acceleration allows for more complex missions which is why light-weight subsystem designs are desirable. For deep-space missions, large antenna apertures are necessary to maintain communication and transmit back scientific data. However, large antennas come with the penalty of additional mass and increased stowage volume. This poses a problem, especially for smaller sailcraft, where the antenna system mass is proportionally larger.

We want to adress this issue by integrating the antennas into the solar sail structure. We propose that integrating the radiating elements of an antenna into the solar sail structure has several advantages. First, this can reduce the system's overall mass. The structures already exist and only small modifications, such as adding or removing metalization or drilling small holes are required to create an antenna. This can also be done with only minimal losses to the sails primary function. Additionally, the available surface area allows for large antenna apertures and high gain. Furthermore, active antennas can be connected to an array, which opens up the potential of beam steering.

Within our paper, we propose two concepts for utilizing the membranes and booms of the sail. The first concept uses the reflective surface of the sail membrane as an antenna. A challenge here is that the RF circuit must be planar, with no additional ground planes used. Because of the thin dielectric, only planar waveguides are possible. Our concept uses spoof surface plasmon polariton waveguides to feed an array of leaky wave antennas. This way, it is possible to achieve a very directional beam. However, this concept requires a thicker metal layer in the area of the RF circuit and also a very flat surface for optimum performance. We discuss the potential performance and issues of this concept in more detail in the paper.

The second concept uses solar sail booms as slotted waveguide antennas. These booms are made from carbon reinforced polymers (CFRP), which itself is a bad conductor for high frequency signals. However, it is possible to turn CFRP structures into working waveguides by either coating the inner surface with a conductive layer or by covering it with a metalized film. We show that leaky wave antennas are possible with existing boom designs. We support the concept with full-wave simulations and 3D-printed prototypes.