Design and Development of Aerogel-Based Antennas for Aerospace Applications

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The design and optimization of communication system technologies in support of aerospace platforms is of paramount interest in the aviation industry, for government (e.g., NASA, DoD, etc.) and the commercial sector. Among the key technologies are transmit/receive (Tx/Rx) antennas required for communications (voice, high data rate video, internet, etc.) and navigation (GPS). A typical commercial and/or military aircraft (e.g., Boeing 737) could have as many as 100 antenna systems. This large number of antennas not only adds weight to the aircraft but also increases the complexity, and challenges the structural integrity of the fuselage. The latter is exacerbated in general aviation aircraft (e.g., smaller Cessna type aircraft) because of more limited space for antenna placement. Therefore approaches that could reduce the mass and number of antennas in the aforementioned aircraft and any other pertinent airborne platform (e.g., long duration, high altitude elevation platforms) without sacrificing performance are highly desired. An innovative approach for lightweight antennas is to use aerogels which are highly porous solids with many interesting properties, including low density and low dielectric permittivity. The latter can reduce Radio Frequency (RF) losses and improve impedance matching in the antenna. We propose to develop antennas incorporating a robust new form of polyimide aerogel developed at the NASA Glenn Research Center to address the challenges of reducing the mass and number of antennas, without sacrificing performance. The polyimide aerogels have superior mechanical strength over other types of aerogels and are easily fabricated into various forms, making them enabling for this application. However, this project requires detailed knowledge of electromagnetic properties of the aerogels. Thus, the objective of this project is to develop aerogels with properties tailored to enable new antenna concepts with performance characteristics (e.g., wide bandwidth and high gain) and material properties (low density, environmental stability, and robustness) superior to the state of practice (SOP). A series of polyimide aerogels has been fabricated to characterize electromagnetic properties, including permittivity, reflectivity, and propagation losses. Experimental results on the relative dielectric constant and loss tangent for the aforementioned polyimide aerogels as a function of density and in the frequency range from 0.050 to 12.2 GHz, will be presented. Prototype planar single-patch antennas from down-selected aerogel formulations were fabricated and benchmarked against current antenna SOP. Plots of the experimentally measured performance of the patch antennas on all substrates correlated very well to simulations. Furthermore, the aerogel antennas exhibit both broader bandwidths, lower mass, and superior gain than SOP counterparts confirming the potential advantages of the aerogel based antennas in the aerospace applications discussed in this proposal. These results as well as suggested future work regarding the demonstration of multi-element aerogel-based antennas arrays will be discussed in more detail at the presentation.