A Metamaterial-inspired Solution to the RF Blackout Problem Associated with Plasmasonic Vehicles

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A solution to the radio frequency (RF) blackout and attenuation problem has been sought since the advent of space exploration. RF blackout happens during the critical atmospheric reentry stage of flight when speeds greater than Mach 10 occur and a plasma sheath forms (plasmasonics). The blackout period can last from 90 seconds to 10 minutes depending on the vehicle's trajectory and angle of attack through the atmosphere. Many approaches to ameliorate the problem have been tried with varying degrees of success. With the recent burgeoning developments in atmospheric hypersonic and commercial exoatmospheric vehicles, the RF blackout problem has seen a resurgence of interest. Suffice it to say that a reasonable solution would greatly benefit both the current endeavors of space flight and hypersonic transport research

Our studies have explored the problem from a materials perspective. Plasmas have been known to exhibit the properties of a negative permittivity dielectric, often referred to as an epsilon negative material (ENG). This negative permittivity is dependent on the plasma density and temperature, which changes throughout the reentry trajectory. Thus, any solution to this problem must be able to compensate to a changing environment, i.e. to a changing negative permittivity.

Our presentation reports a feasible approach to the solution using a tunable, artificial, mu-negative (MNG) material based on varactor-loaded split-ring resonators (SRRs). The MNG material is designed to create a conjugate match to the plasma. The metastructure formed as the conjugate matched pair of the MNG material with the ENG plasma region acts as a composite layer of double-negative (DNG) material at the frequency of operation. Thus, wave propagation is possible in it, thus reducing the RF attenuation and resulting in transmission of electromagnetic waves through the plasma region into free space beyond it. Transfer matrix method (TMM) calculations along with unit cell simulations describe the transmission and reflection properties of the metastructure. Simulations of finite-area MNG and plasma layers combined with a Huygens dipole antenna indicate that reasonable levels of signal transmission through the plasma region can be obtained.