Plasma Windowing for Hypersonic Radio Communications

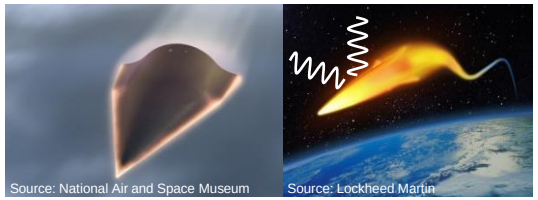
S.D. Sifferman, B. Sallee, R. Noster
Systems and Processes Engineering Corporation, Austin, TX, USA

IMS Connecting Minds. Exchanging Ideas.

The Coolest Ideas Under the Sun SAN DIEGO 2023

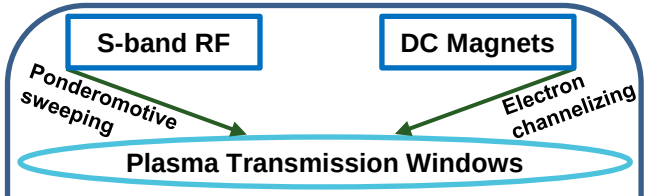
STATUS QUO

Radio Comms for Hypersonic Vehicles



- ✓ Plasma sheaths around hypersonic flight vehicles cause EM interference and radio blackout
- ✓ Radio blackout is a substantial communications issue during extended atmospheric flights

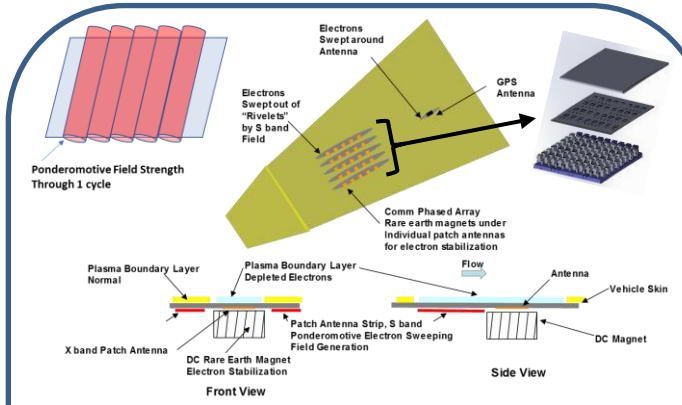
NEW INSIGHTS



Two-prong approach to open transmission windows in the plasma sheath

- ✓ S-band RF field upstream from antenna array
  - ➢ RF field induces ponderomotive force
  - ➢ Electrons are “swept” into channels
- ✓ Constant magnetic field under antenna array
  - ➢ Stabilizes the electrons within channels
  - ➢ Clears transmission windows over antenna

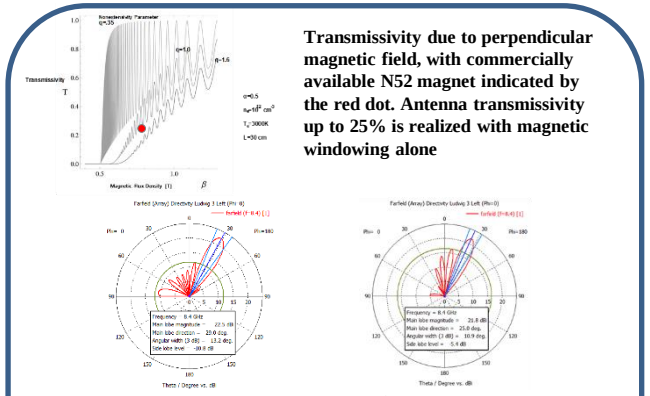
DESCRIPTION



Antenna System Elements

- ✓ **S-band RF ponderomotive field generators**
  - ➢ 3.4 GHz induces ponderomotive electron sweeping
  - ➢ Radiated power absorbed in plasma flow
- ✓ **DC rare earth magnets under comms antenna**
  - ➢ 0.75 T rare earth (Nd) magnets under each antenna array element
  - ➢ Plasma free electrons forced out of resonance with communications frequencies
  - ➢ Longitudinal magnetic flux density causes net phase rotation on antenna transmission
  - ➢ Steering angle reduced from 29º to 25º with applied magnetic field
- ✓ **Ku band steerable phased array antenna**
  - ➢ 8x8 element array; ~9.42 mm^2 per element
  - ➢ EIRP ~40 dBW
  - ➢ 240 mW/element

QUANTITATIVE IMPACT



Transmissivity due to perpendicular magnetic field, with commercially available N52 magnet indicated by the red dot. Antenna transmissivity up to 25% is realized with magnetic windowing alone

Antenna steering angles without (above, left) and with (above, right) an applied magnetic field. The simulated steering angle decreases from 29º to 25º with an applied 0.75 T magnetic flux density.

PROPOSED CONCEPT GOALS

Integrated antenna system solution for plasma-sheathed hypersonic flight vehicles:

- ➢ Plasma free electrons channeled between antenna array columns via ponderomotive sweeping
- ➢ Up to 25% antenna transmittivity via DC magnetic windowing only
- ➢ Transmittivities up to 80% possible using combined S-band sweeping and DC magnetic channeling