VLF/LF Generation via Electrically Short Plasma Antennas

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There is great interest in the efficient generation of VLF and LF (3-300 kHz) radio waves. Radio waves in these frequency bands have been used for long range and undersea communication and ionospheric remote sensing. More recently, applications have developed ranging from navigation to subterranean detection and imaging.

The key technical challenge is that the wavelengths are extremely long (1-100 km). Traditional VLF antennas are large, inefficient, and expensive to operate. Reasonable efficiency can be achieved via the `top hat' impedance matching scheme that adds the reactive components to create a resonant antenna. Unfortunately, in practice the top hat has a very large physical footprint, works in a narrow frequency band, and is inhibited by practical limitations below approximately 8 kHz.

In this presentation, we consider a potential application of plasma-based antennas as a way to control input impedance over a range of frequencies, as an alternative to the top hat solution. A rapidly-modulated plasma column can be utilized to modify antenna input impedance. We therefore seek a plasma device with rapid ionization and quenching while also conducting sufficient signal power to achieve long-distance radiation.

This work explores a variety of gas mixtures and ionization methods both experimentally and through 2-D simulation models to identify suitable systems to achieve the conductance metrics. Experimental measurement of these parameters at the required timescales presents its own set of technical and scientific challenges. These measurements require a unique set of tools and techniques as many typical plasma measurements are performed on steady-state plasmas. This work aims to determine the electron number density, electron temperature, and collision frequency that provide the optimal balance of modulation speed and conductivity for maximum efficiency.