Radiation Characteristics of an Antenna through a Plasma Flow with Ion Acoustic Instabilities

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We investigate an antenna radiating though a weakly ionized plasma flow with ion acoustic instabilities. The electron density fluctuations are characterized by its spectral density function which has been obtained by numerical simulations in our previous work. It is assumed that they are stationary and statistically homogenous in azimuth. The flow is bounded on one side by a perfectly conducting plane, and on the other by free space. The antenna source signal has finite bandwidth with frequencies well above the plasma frequency of the flow. The electromagnetic waves excited by the antenna interact with the density fluctuations of the flow. This creates current fluctuations in the flow, which in turn radiate and distort the radiation characteristics of the antenna. The goal of this paper is to quantify and understand the nature of such distortions.

It is convenient to decompose the fluctuation electric field into a coherent part and a diffuse part. Noting the small amplitude of fluctuations of the flow we seek a perturbation solution for the coherent and diffuse waves. Using a first order approximation we solved the coherent wave equation and obtained the mean Green's function. We use this to compute the coherent radiation pattern of the antenna. Due to multiple scattering in the flow the coherent waves undergo a finite attenuation which is frequency dependent. Leaving aside this behaviour, we find that the radiation characteristics of the coherent waves are very similar to that of the antenna in free space.

We carried out similar analysis for the diffuse waves and found that their characteristics are quite different from those of the coherent waves. We obtained the diffuse intensity as a convolution of the source signal with space-time spectral density of flow fluctuations. This is a constrained convolution because the convolution domain is constrained by the dispersion relation of the ion acoustic waves. This leads to shifts in wave number and frequency of the radiated fields. Thus the diffuse radiation pattern is considerably altered from that of the source signal. Also, its spectral content is quite distorted such that the usual deconvolution processing will not recover the signal. A direct consequence of this is that even a monochromatic signal will radiate as a polychromatic signal. A key quantity is the extinction coefficient, which determines the thickness of the flow. For thin flows the coherent part is dominant, and for thick flows the diffuse part is dominant. We considered several numerical examples to illustrate these findings.