Monday, 7 June 1993
9:45 am – Room 303
ORAL SESSION 1D
Basic Plasma Phenomena
Chair: R. L. Stenzel

1D1-2

Sheath Waves on Conductors in Plasma

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The ion sheath is the familiar region of low electron density that exists adjacent to any material surface immersed in a plasma. Less familiar is the fact that, when the material surface is a conductor, the sheath becomes a channel for guided waves propagating parallel to the surface. In the frequency domain, these "sheath waves" have remarkable properties of low-attenuation passbands, high-attenuation stopbands, and striking effects caused by plasma anisotropy. This paper reviews recent progress in sheath wave research, with emphasis on ionospheric tether experiments and implications for large structures in space.

When the plasma is homogeneous, isotropic and cold, and the sheath is represented as a vacuum gap, sheath waves are surface waves that propagate from zero frequency up to $1/\sqrt{2}$ times the plasma frequency. Sheath waves tend to follow curved surfaces, an example being an open-ended wire helix whose measured input impedance clearly shows multiple resonances characteristic of the total wire electrical length.

In a magnetoplasma, for propagation parallel to the magnetic field, sheath waves can propagate from zero frequency to $1/\sqrt{2}$ times the upper hybrid frequency, for the case when the cyclotron frequency is less than the plasma frequency. In the range from zero frequency up to the cyclotron frequency, the attenuation is particularly low, and near the cyclotron frequency there is a local increase in attenuation, observations that have been made in calculations for waves over a planar surface. The same observations have been made experimentally in the ionosphere, for propagation on a long wire parallel to the magnetic field, in the course of the "OEDIPUS" tethered-rocket experiment. As well, these ionospheric experiments showed that the sheath waves are easily excited. Moreover, the OEDIPUS experiments displayed well-defined sheath-wave attenuation bands exactly corresponding to the cyclotron harmonic wave passbands. Since cyclotron harmonic waves propagate across the magnetic field, their radiation perpendicular to the wire axis provides an explanation for the related attenuation bands, an explanation that is not only qualitative but also supported by calculations based on simplified transmission-line theory.

For propagation across the magnetic field, less is known, but calculations and laboratory measurements have been carried out for planar geometry and a magnetic field perpendicular to the surface. In this case, the previously mentioned passband from zero frequency to the cyclotron frequency becomes a stopband, leaving propagation only in the range from the cyclotron frequency to $1/\sqrt{2}$ times the upper hybrid frequency.

For large structures in low earth orbit, the implication is that sheath waves could carry low-frequency interference from one point to another, with received-signal amplitudes higher than in the absence of plasma. Computations and laboratory experiments will be described in support of this assertion, with reference to the Space Shuttle and the Space Station.

1D3-4

Chaos in Gas Discharges

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Many gas discharges exhibit natural oscillations which undergo a transition from regular to chaotic behaviour by changing an experimental parameter or by applying external modulation. Besides several isolated investigations, two classes of discharge phenomena have been studied in more detail: Ionisation waves in medium pressure discharges and potential relaxation oscillations in filament cathode discharges at very low pressure. The latter phenomenon will be discussed by comparing experimental results from different discharge arrangements with particle-in-cell simulations and with a model based on the van-der-Pol equation.

The filament cathode discharge has two stable modes of operation: the low current anode-glow-mode and the high current temperature-limited-mode, which form the hysteresis curve in the I(U) characteristics. Close to the hysteresis point of the AGM periodic relaxation oscillations occur. We demonstrate that the AGM can be understood by ion production in the anode layer, stopping of ions by charge exchange, and trapping in the virtual cathode around the filament. The relaxation oscillations consist of a slow filling phase and a rapid phase that invokes formation of an unstable double-layer, current-spiking, and ion depletion from the cathodic plasma. The relaxation oscillations can be mode-locked by external modulation. Inside a mode-locked state, a period doubling cascade is observed at high modulation degree.