BOSTON UNIVERSITY

SPACE PHYSICS SEMINAR

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"Nonlinear Resonant Circuit Models of Space Plasma Physics"

Thursday, September 13, 2012
Refreshments at 3:30pm in CAS 500
Talk begins at 4:00pm in CAS 502

Abstract:

Electrical engineering teaches resonant circuit fundamentals that can provide insights to a wide variety of space plasma physics applications. By putting a capacitor and inductor in parallel, one forms a resonant circuit. An external oscillating voltage source can excite large voltages and currents in the resonator that are only limited by conductive losses. The resonant frequency divided by the effective bandwidth is called the circuit Q. Resonant electrical devices such as a Tesla Coil generate large enough electric fields to produce atmospheric breakdown and artificial lightning.

For the first example, consider the process for generation of a sequence of substorms in the earth's magnetosphere and ionosphere. The earth's magnetosphere can be modeled as a continuously driven electric circuit with a threshold for a discharge. The solar wind extends the field lines in the magnetotail until a discharge event called reconnection. This reconnection initiates a substorm that can impact power lines and communications. After each reconnection, the magnetotail is again extended by the solar wind until another discharge occurs. The period between reconnection events can be influenced by high Q resonant oscillations in the plasma that affects the discharge threshold. A chaotic circuit model is used to illustrate the complex dynamics of time period between substorms.

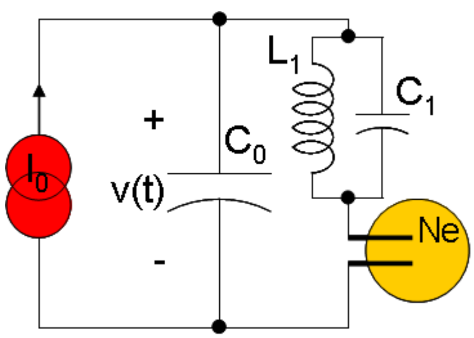

Figure 1. Circuit model for reconnection in the magnetotail. The current source represents the solar wind and the neon bulb provides a discharge path after the capacitor has charged to the reconnection threshold. The tuned L-C circuit represents oscillations in the magnetotail plasma.

Second, consider the effects of blasting the ionosphere with 3.6 Mega Watts from the HAARP transmitter in Alaska. High power radio waves in the ionosphere are used to generate artificial aurora and artificial plasma layers. The transmitted pump wave decays parametrically into plasma waves that accelerate electrons to supra-thermal energies. The high energy electrons ionize and excite the neutral gas by inelastic collisions. This process is illustrated by a parametric oscillator circuit model with several tuned circuits. In this model, the high power transmitter is represented as a pump generator. The pump decays into high and low frequency waves that associated with plasma resonances. Each tuned circuit in the model represents either low frequency waves (Whistler, Ion Acoustic, Alfven, Ion Bernstein) or high frequency Waves (Electromagnetic, Electron Plasma, Electron Bernstein). The nonlinear coupling between these waves is provided by multiplication terms in the continuity and momentum equations that describe the plasma. These and other simple electrical circuits help provide an intuitive understanding of complex space plasma physics.