Maxwell's Demon and Reciprocity

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Background:

In 1867, Peter Guthrie Tait asked his friend, James Clerk Maxwell, for his assistance in explaining the second law of thermodynamics. Just then coming into vogue, scientists recognized that the second law of thermodynamics placed fundamental limits on the availability of energy in thermodynamic systems. One disturbing implication is the inevitable "heat death" of the universe, as the universe irreversibly winds its way down to a state of thermal equilibrium.

Maxwell offered an intriguing thought experiment to "refute" the implications of the second law. Suppose a "very observant and neat fingered being" controlled a frictionless passageway between two chambers of gas in a thermal equilibrium. This being, or "demon," could selectively open and close the passageway to concentrate "hotter" molecules of gas in one chamber and colder molecules of gas in the other chamber.

Maxwell's demon is an example of what is called a "perpetual motion machine of the second kind." A perpetual motion machine of the second kind (PMM2) violates the second law of thermodynamics. It decreases the net entropy of the universe, creating order from disorder. Today, it is generally recognized that any physically realizable demon requires input work to acquire the information on which it acts. Thus the second law of thermodynamics is ultimately upheld. Nevertheless, Maxwell's demon continues to excite imaginations to the present day

Thermodynamics and Fundamental Antenna Physics:

Thermodynamic reasoning can be used to establish fundamental principles governing the behavior of antennas. For instance, Slater demonstrated the equivalence of the radiation and absorption patterns of a point dipole by a detailed calculation of their power flow [J.C. Slater, ***Microwave Transmission***, (New York: McGraw-Hill Book Company, Inc., 1942) pp. 235-245.]. He further argued from the statistical principle of detailed balance that absorption and radiation of a dipole in thermal equilibrium with its surroundings must exactly balance in any particular infinitesimal solid angle.

The present paper will use the concept of Maxwell's Demon to provide a simple and sweeping proof of the principle of reciprocity. The equivalence of transmit and receive antenna patterns will be discussed, as well as the equivalence of transmit and receive antenna efficiencies. Finally, this paper will argue that thermodynamic considerations allow limits to be placed on the scattering and reflection of antennas, as well as the efficiency of frequency multipliers.