HF-Induced Irregularities and Scintillation Effects Investigated with the High Frequency Active Auroral Research Program (HAARP) Facility

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The interaction of high power, high frequency (HF) radio waves near the local plasma frequency in the ionosphere generates a wide range of well-known effects that include elevation of the electron temperature, particle acceleration, enhanced atmospheric airglow, stimulated electromagnetic emissions and plasma turbulence leading to the formation of electron density irregularities. Irregularities are known to occur over a wide range of scale sizes, from meter-scale to tens of kilometers depending on heating duration, power and geophysical conditions.

Recently it has been demonstrated that HF-induced airglow effects are significantly enhanced when the transmitted beam is pointed along the magnetic zenith direction. Subsequently it was shown theoretically that the generation of upper hybrid waves, and their associated electron acceleration, is favored by this field-aligned geometry. Upper hybrid waves are also associated with the formation of electron density irregularities a few meters in scale size.

Scintillations of radio waves in the UHF and VHF radio bands, however, are caused by irregularities of a few hundred meters to kilometer scale sizes which are known to result from extended-duration HF heating (tens of seconds or more). The processes responsible for these large-scale irregularities are not entirely understood and it is not clear whether the formation of such irregularities is achieved more effectively by magnetic zenith or vertical heating. While upper hybrid wave excitation may play a role in large-scale irregularity formation as the waves become trapped in density depletions, thereby intensifying and expanding the depletions, other large-scale processes such as the swelling effect of electric fields in the standing wave pattern that occurs in vertical heating may enhance the generation of large-scale fluctuations.

The HAARP facility in Alaska features rapid beam steering such that experiments to investigate the formation of medium- to large-scale irregularities as a function of beam position can be readily conducted. Scintillation techniques were used to monitor HF-induced irregularity formation in a series of observations conducted in November 2007. Prelimary results from those observations are presented along with recommendations for future experiments designed to enhance HF-induced plasma effects on radio wave propagation.