Investigation of Stimulated Electromagnetic Emission Second Harmonic Generation

A. D. Yellu[1], W. A. Scales[1], A. Mahmoudian[2], P. A. Bernhardt[3], and C. L. Siefring[3]

[1] Bradley Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA, USA

[2] Department of Electrical and Computer Engineering, InterAmerican University, Puerto Rico

[3] Plasma Physics Division, Naval Research Laboratory, Washington DC, USA

Nonlinear processes arise when a high power, high frequency electromagnetic wave interacts with ionospheric plasma. The nonlinear processes, mainly parametric decay instabilities, manifest as secondary radiation known as stimulated electromagnetic emissions (SEE). SEE within ±1 kHz of the pump wave frequency is known as narrowband SEE (NSEE). SEE outside ±1 kHz of the pump wave frequency is known as wideband SEE (WSEE). Electron temperature, ion composition, dynamics and turbulence state and other useful ionospheric diagnostics can be obtained from analyses of an SEE spectrum. The existence of SEE at and in the vicinity of the second harmonic of the pump wave frequency is known as secondary harmonic generation (SHG). In the field of Laser Plasma Interactions (LPI), theoretical and experimental investigation of SHG is longstanding. SHG has been developed into a powerful diagnostic tool in LPI yielding diagnostics such as the electron density, velocity of plasma resonance region, scale length of electron density inhomogeneity etc. SHG has the potential of producing similar diagnostics for the ionosphere. Results are presented for experiments that were conducted in September 2017 at the High Frequency Active Auroral Research Program (HAARP) facility to investigate NSEE, WSEE, SHG and their interrelationships. The pump frequency was stepped near the third harmonic of the electron gyrofrequency. In one variation of the experiments, the transmit power was linearly increased from a low value to the maximum available transmit power for the heating cycle at each frequency whilst in the other, the power was maintained at the maximum available transmit power throughout each heating cycle. Analyses of SEE spectra led to the following conclusions: (1) For the experiment in which the transmit power was linearly increased, NSEE due to stimulated Brillouin scatter (SBS) within 30 Hz of the pump wave frequency shows similar transmit power dependence as SEE within 30 Hz of the second harmonic of the pump wave frequency and both SEE are suppressed near the third electron gyrofrequency (2) For the experiment in which the power was maintained at a maximum throughout the heating cycle, the SBS spectral line near the power and the downshifted decay line at the second harmonic are present during only the first few seconds of the heating cycle (3) Downshifted maximum (DM) WSEE line power is anti-correlated with the that of the second harmonic decay line. Initial Particle-In-Cell (PIC) simulations will be presented to interpret these observations.