

## **Recent Observations and Modeling of Ionospheric Stimulated Electromagnetic Emissions**

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High power electromagnetic (EM) waves transmitted from the ground interact with the local plasma in the ionosphere and can produce Stimulated Electromagnetic Emissions (SEEs) through the parametric decay instability (PDI). The classical SEE features known as wideband SEE (WSEE) with frequency offset of 1 kHz up to 100 kHz have been observed and studied in detail in the 1980s and 1990s. A new era of ionospheric remote sensing techniques was begun after the recent update of the HF transmitter at the High-Frequency Active Auroral Research Program (HAARP) in Alaska. Sideband emissions of unprecedented strength have been reported during recent campaigns at HAARP, reaching up to 10 dB relative to the reflected pump wave, which are by far the strongest spectral features of secondary radiation that have been reported. These emissions known as narrowband SEE (NSEE) are shifted by only up to a few tens of Hertz from radio-waves transmitted at several megahertz. One of these new NSEE features are emission lines within 100 Hz of the pump frequency and are produced through magnetized stimulated Brillouin scatter (MSBS) process.

Stimulated Brillouin Scatter (SBS) is a strong SEE mode involving a direct parametric decay of the pump wave into an electrostatic wave (ES) and a secondary EM wave that sometimes could be stronger than the HF pump. SBS has been studied in laboratory plasma experiments by the interaction of high power lasers with plasmas. The SBS instability in magnetized ionospheric plasma was observed for the first time at HAARP in 2010. Our recent work at HAARP has shown that MSBS emission lines can be used to assess electron temperature in the heated region, ion mass spectrometry, determine minor ion species and their densities in the ionosphere, study the physics associated with electron acceleration and artificial airglow.

Here, we present new observations of NSEE features at the new mid-latitude heating facility at Arecibo. This includes the direct mode conversion of pump wave through MSBS process. Collected data using ground-based SEE receiver, ISR, ionogram, as well as satellite observations will be discussed. The different characteristics of parametric decay instabilities in the high and mid-latitude will be compared. Preliminary theoretical and computational modeling of mid-latitude NSEE will be presented.