The Discovery of Novel Ionospheric Phenomena using Ionospheric High Frequency Software-Defined Radar

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Classical ionospheric sounders have been used since 1930s to study ionospheric phenomena. However, there is still a significant lack of understanding of both temporal and spatial evolution and dynamics of ionospheric plasma instabilities, particularly, at mid-latitude regions. Due to the nature of their high temporal variability, these ionospheric events are best detected and studied with radar systems. In this paper, we report novel ionospheric plasma instabilities observed with Penn State Ionospheric Radar Imager (PIRI); a new low-cost, low power (600W), and software-defined HF radar system. These unique observations were captured at two mid-latitude locations: Rock Springs, PA (40.71°N, 77.97°W, radar operated with center frequency $f_o = 5.125$ MHz) and Arecibo, Puerto Rico (18.36°E, 66.75°S, radar operated with center frequency $f_o = 4.42$ MHz). PIRI was deployed at Arecibo in March 2017 as a complementary sensor during the HF heating campaign that took place at Arecibo Observatory. A total of four (two natural and two with artificial modification) events from these two locations are presented and discussed. One natural event resembles Sporadic-E phenomena that lasts for about five-hours. The other natural event depicts highly structured echoes from plasma inhomogeneities from F-region altitudes that appears like mid-latitude Spread-F. The two artificially induced events were detected when the HF Heater operated in CW mode at 5.125 MHz and in pulse mode at 8.175 MHz. When the HF Heater operated in CW mode, PIRI captured an event that has Spread-F signatures that appears to be induced due to artificial modification of the ionosphere. During pulse mode HF Heater operation, PIRI detected echoes that do not fall into any ionospheric phenomena that has been previously reported. Radio science scattering of these events will be discussed as well as future possible deployment of PIRI with at lest three sets of active receiver antennas for dual polarization interferometry configuration will be presented.