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An MF/HF Radio Array for Imaging of Stimulated Electromagnetic Emissions

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An important discovery of ground-based high-power high-frequency (HF) ionospheric radiowave interaction (a.k.a. heating) experiments is the strong dependence of the radio emissions from the ionosphere during these experiments (commonly called stimulated electromagnetic emissions or SEE) on the frequency difference between the HF pump and the gyroharmonic frequencies of the geomagnetic field. Experimental results also show that several of the emission lines in the SEE spectrum depend on the angle between the pump beam and the field. These results indicate that SEE processes depend strongly on the relative geometry of the pump beam and the field.

The Aguadilla Radio Array (ARA) is a 2 to 25 MHz (medium and high frequency or MF/HF) radio imaging array to be installed in Aguadilla in northwestern Puerto Rico. The array will consist of multiple antenna elements, each of which is an active (electrically short and impedance-matched) crossed electric dipole. Elements in the array will be arranged in a partly ordered and partly semi-random pattern providing a good distribution of baseline vectors, within an area of about 300 meters in diameter, with 7-meter minimum spacing to eliminate spacial aliasing up to 21 MHz. Phase is maintained between the antenna elements via cabled connections to the equipment shelter.

A primary scientific goal of the array has been to study the mechanisms of ionospheric radio emissions stimulated by the Arecibo Observatory (AO) high-power HF radio transmitter, and their dependence on the geometry of the radiowave pump with respect to the geomagnetic field, through the creation of high resolution radio images of the emission region. The collapse of the observatory's 900-ton instrument platform on December 1, 2020, resulted in the loss of the Arecibo HF transmitting antenna, as well as most of the other AO radio and radar systems. However, plans are being discussed for the restoration of Arecibo HF capabilities, perhaps as early as 2022 (see *Bernhardt et al.* and *Breakall et al.*, session HG1, and *Isham et al.*, session G06, this meeting).

Other important goals of the Aguadilla array include the study of space weather, ionospheric structure and dynamics, plasma physics, and radio propagation, through the use of coherent radar imaging in collaboration with the University of Colorado and NOAA Versatile Interferometric Pulsed Ionospheric Radar (VIPIR) transmitter located at the USGS San Juan Observatory in Cayey, 110 km from Aguadilla. In addition, a recently-submitted proposal would provide funding for a second HF radar transmitter near Arecibo Observatory, 40 km from Aguadilla.

Relocatable cable-less antenna elements will also be included, in which phase is maintained between elements through the use of GPS-disciplined rubidium clocks. These may be used independently or together with the main array. For example, five cable-less elements could be located in a ring of about 300-m radius around the central core, providing a roughly three times expanded region in *uv* space for improved resolution. A second ring of seven elements at about 600-m radius could provide an additional two-fold increase in image resolution. Elements placed at farther locations could provide additional resolution for even more-detailed imaging.

The ARA will be an ideal instrument for collaboration with overflights by satellites, for example with onboard HF receivers, such as has been done using the Radio Receiver Instrument (RRI) on the ePOP payload of the Canadian Cascade, Smallsat and Ionospheric Polar Explorer (CASSIOPE) satellite. ARA would provide images of radio emissions from below the ionosphere, while the satellite records radio signals from above the emission region.

The radio and radar capabilities of the array can also be used to study meteors and lightning, and may have applications in radio astronomy. In addition to scientific research, the goals of the project include the further development of radio sounding, polarization, interferometry, and imaging techniques, and training of students at the university and high school levels.