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A 0.3 to 30-MHz Antenna Array for Radio and Radar Imaging of the Ionosphere

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Abstract

The atmosphere is a source of natural radio emissions in the medium-frequency (MF) and high-frequency (HF) bands (0.3 to 30 MHz). In addition to natural emissions, artificial emissions from the ionosphere can be stimulated using high-power HF radiowave ionospheric modification facilities, one of which is located at Arecibo Observatory in Puerto Rico. The Aguadilla Radio Array will measure these emissions and will also function as a bistatic imaging radar receiver, in collaboration with the VIPIR HF radar located at the USGS San Juan Observatory in Cayey, Puerto Rico. Radio and radar data recorded by the Aguadilla array can be used to study lightning and meteors, radar images of the ionosphere will contribute to the study of space weather, and radio images of artificial emissions will contribute to the goal of better understanding the geometry and mechanisms of stimulated radio emissions.

1 The Aguadilla Radio Array

The Aguadilla Radio Array, which will operate in the medium and high-frequency (0.3 to 30 MHz) radio bands, is currently being installed at the Interamerican University Aguadilla Campus located in northwestern Puerto Rico (see figure 1). The array is intended for broad-band radio and bistatic radar observations of the ionosphere.

The array will consist of 36 antenna elements, each of which is a crossed pair of electromagnetically short active electric dipoles (see figure 2). Elements in the array will be arranged within a roughly 300-meter-diameter area, in a partly ordered and partly semi-random pattern, providing a good distribution of baseline vectors, with 6-meter minimum spacing in order to eliminate spacial aliasing up to 25 MHz (see figure 3). The receivers have 16-bit ADCs sampling at 120 MHz, and are atmospheric noise limited. Data is transferred via USB 3.

In addition to radio observations, the array is designed for broad-band, bistatic radar observations in collaboration with the University of Colorado and NOAA Versatile Interferometric Pulsed Ionospheric Radar (VIPIR) transmitter [1, 2, 3] located at the USGS San Juan Observatory in Cayey, Puerto Rico (see figure 1).

The Aguadilla array will receive 5.1 and 8.175 MHz ionospheric radio emissions, and harmonics and subharmonics of those emissions, from above Arecibo, and 2 to 25 MHz bistatic radar transmissions from Cayey. The array will be located 41 km from the Arecibo Observatory and 109 km from the Cayey radar along a shared line-of-sight (see figure 1).

Each antenna element will consist of a short active electric crossed dipole antenna (see figure 2). . The array can receive between 0.3 and 30 MHz, with the shortest spacing between elements equal to 1/2 wavelength at 25 MHz, or 6 meters, to avoid spacial aliasing and potential confusion among signals, such as wanted radio emissions and unwanted radio interference, up to 25 MHz.

Knowledge of the phase between signals from each antenna element is critical for radio and radar interferometry and imaging. Phase will be maintained between antenna elements via cabled connections to a central location.

In addition, ten of the crossed antennas and receivers will be capable of maintaining phase through the use of GPS-disciplined rubidium clocks. These ten elements will be transportable and may be used together with the main array or as independent radio and radar receivers. A primary goal of this capability is to allow the use of longer baselines between antenna elements, for example 100's of meters to kilometers, and thus increase the spacial resolution of the measurements.

For example, the transportable elements might be used in a large circular array (see figure 4) to provide high spacial resolution within the beam of the Arecibo Observatory high-power HF transmitter, the solid angle of which is about equal to the resolution of the main array. Alternatively, several elements could be located in a 600-m-diameter ring around the main array, providing a roughly four times expanded region in u-v space for improved image resolution and quality. The transportable elements may also be used 10's or 100's of km from the main array, for example to measure signals from the emission region above Arecibo at a variety of viewing angles, or to observe a variety of bistatic radar scattering regions.

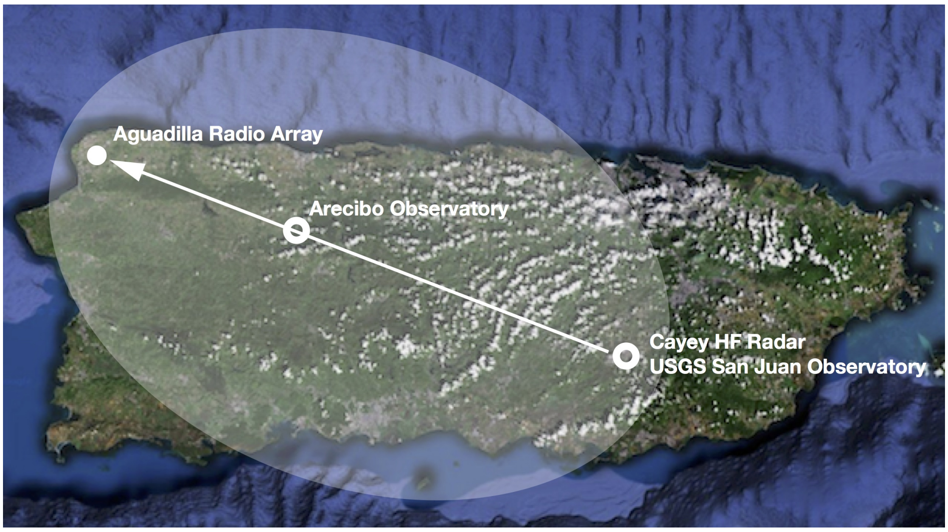

Figure 1. The locations of the Aguadilla Radio Array, the Cayey VIPIR HF radar, and the Arecibo Observatory, and a cartoon (transparent white region) of the possible region of bistatic HF radar scattering. The Aguadilla array will be 109 km from the Cayey radar and 41 km from the Arecibo Observatory. (Background image from maps.google.com.)

Figure 2. An antenna and tower similar to those to be used for the Aguadilla Radio Array. The dipole elements are 1.8 meters from end to end. The small box above the antenna contains the preamplifier.

2 Discussion and Conclusion

The atmosphere is a radio source at many frequencies. In particular, ionospheric emissions in the medium and high-frequency bands have been studied for many years. In addition to natural emissions [4], artificial radio emissions can be produced using high-power HF radiowave ionospheric modification transmitters such as the one at Arecibo Observatory in Puerto Rico [5, 6, 7].

The primary scientific goals of the Aguadilla Radio Array include the study of the mechanisms of ionospheric radio emissions, which can be stimulated by the Arecibo Observatory high-power HF radio transmitter, through the creation of high-resolution radio images of the emission region, and the study of ionospheric structure and dynamics via wide-area coherent radar imaging of the ionosphere in collaboration with the VIPIR HF radar in Cayey, Puerto Rico. High-resolution radio images of artificial emissions from plasma turbulence will contribute to the goal of better understanding the geometry and mechanisms of the radio emission processes [8], and wide-area radar images of the ionosphere will contribute to the study of space weather, including gravity waves and coupling between atmospheric regions [9].

In addition, radio polarization studies of ionospheric plasma turbulence, both natural and artificial, are still in their infancy, and the full polarization capabilities of the array will shed new light on the processes responsible for both types of turbulent phenomena [10]. The Aguadilla array will also be capable of performing radio and radar measurements for studies of lightning [11] and meteors [12, 13].

The goals of the Aguadilla Radio Array project also include the development of radio sounding, polarization, interferometry, and imaging techniques [8, 14], and training of students at the university and high school levels. We welcome collaborations in the use of the Aguadilla Radio Array in all areas of research, development, and education.

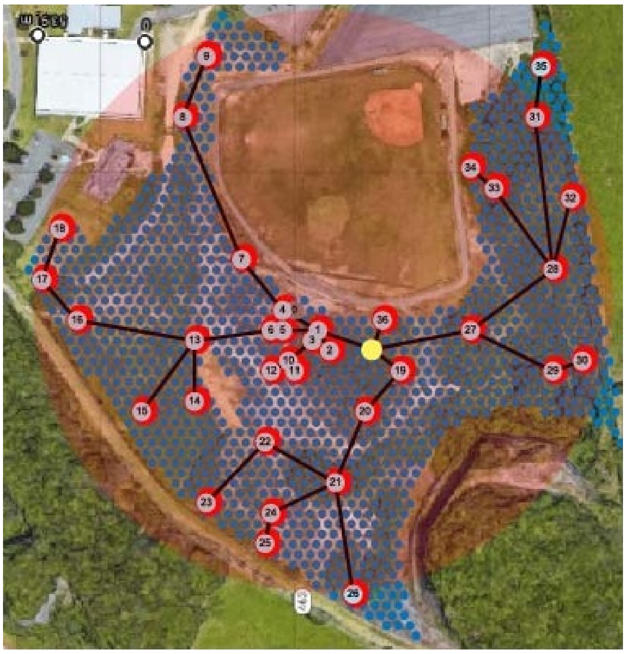

Figure 3. A possible layout for the Aguadilla Radio Array. The light red tinted circle nearly filling the image is 300 meters in diameter. The small yellow circle just below and right of center is the location of the equipment shelter. (Background image from maps.google.com.)

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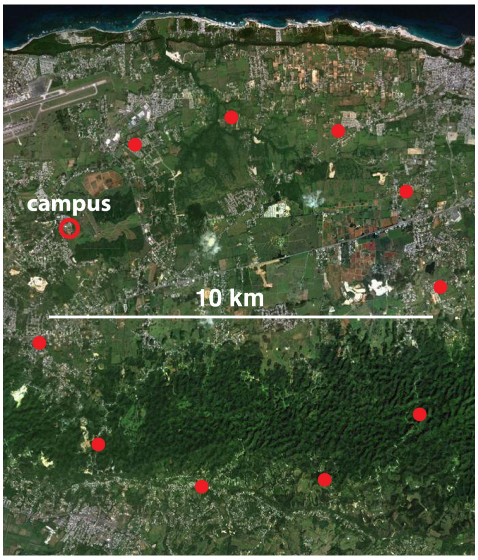

Figure 4. A potential arrangement for the transportable receivers of the Aguadilla Radio Array. "Campus" indicates the main array, located on the Interamerican Aguadilla campus. (Background image from maps.google.com.)