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Reconstructing the Arecibo Observatory with an Upgraded Design of the High-Power HF System at Arecibo, Puerto Rico

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For over 50 years, the Arecibo Observatory employed a 305-meter dish for active and passive studies of the upper atmosphere, radar astronomy of the sun planets, sun and asteroids and radio astronomy. The ionospheric modification instrument, with the largest radio transmission dish in the world, had two High Frequency (HF) transmitters at 5.125 MHz and 8.175 MHz used for nonlinear interactions in the ionosphere and a 430 MHz radar to measure these interactions and impacts on the space plasma environment. Ionospheric modification with high power radio waves was used to produce large areas of plasma irregularities and to create artificial plasma clouds.

With the recent destruction of the Arecibo platform, dish, and transmission lines, rebuilding the facility for radio astronomy, radar astronomy, incoherent scatter radar (ISR) and ionospheric modification is challenging. Members of the Active Ionospheric Physics Community have realized that the most modest proposal of reconstructing the "HF facility" should be considered first. Reconstitution of the high power HF system with enhanced capabilities to perform HF research at Arecibo beyond that of the previous facility is possible in a relatively short time. The enhancement to the reconstituted HF facility include (1) wider frequency agility for tuning to resonances that better couple into the plasma, (2) full beam steering that removes antenna patterns restrictions of the former vertical antenna pattern, (3) and an HF feed system for excitation of orbital-angular-momentum (OAM) beams next generation plasma structuring and HF radar applications. With these upgrades, the new Arecibo HF Facility will provide unique capabilities for studying and mitigation of the impact ionospheric irregularities on satellite navigation and communications, for production of stable plasma mirrors below the dynamic ionosphere, and HF sounding of the sun for detection of coronal mass ejections and the moon for penetration below the lunar surface. There is obviously a strong desire of have an HF facility at Arecibo to be supported by a number of ground diagnostics including the HF radio imaging receivers, wide and narrow field-of view imagers, HF sounders with angle-of-arrival capability and, eventually, an incoherent scatter radar (ISR). For now, a stand-alone HF transmitter system could provide excellent scientific capabilities for the ionospheric research community.

The engineering of the Arecibo HF upgrades during reconstruction involves improving the high-power electromagnetic radio system. Three crossed dipoles were fed by six transmitters with powers up to 600 kW were used to drive the Arecibo dish to produce in a narrow-band (30 kHz) beam at 5.1 MHz. Moving and rotating the reflector mesh over the Arecibo dish was not previously possible because of vertical support cables attached to the 900-ton feed. Without these support cables, pointing of the HF beam is now possible with an articulated secondary mesh. A new six-dipole feed for the Arecibo Observatory has been designed to increase the bandwidth of the transmissions and to shape the antenna pattern in to either a pencil or rings. A tangential ring of dipoles around the center of the 300-m Arecibo dish will each continuously fed with 100 kW to reflect off a hexagonal mesh, which is a secondary reflector. When the six antennas are phased to produce an L = 0 orbital-angular-momentum (OAM) mode, the system will have an effective radiated power (ERP) of about 150 MW. This pencil beam can be steered of zenith by as much as 20 degrees by moving and tilting the secondary reflector mesh. With the pencil beam, interactions at the bottom of the ionosphere produce unstable, descending plasma clouds. The new configuration of six dipoles can be phased at L = ± 1 and L = ± 2 Modes to produce ring-beams with peak ERPs of 12 and 5 MW, respectively. Phasing of the dipoles can yield multiple, oblique beams with zenith offsets as much as 45 degrees. These beams can be formed into six different azimuth directions. The added versatility of the ionospheric modification system at Arecibo will be used to control the ionosphere in terms of adding field-aligned irregularities and producing stable plasma clouds at a desired location, suitable for scattering of HF and VHF radio waves.

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