History of Antenna Technology at the Arecibo Observatory, Arecibo Puerto Rico

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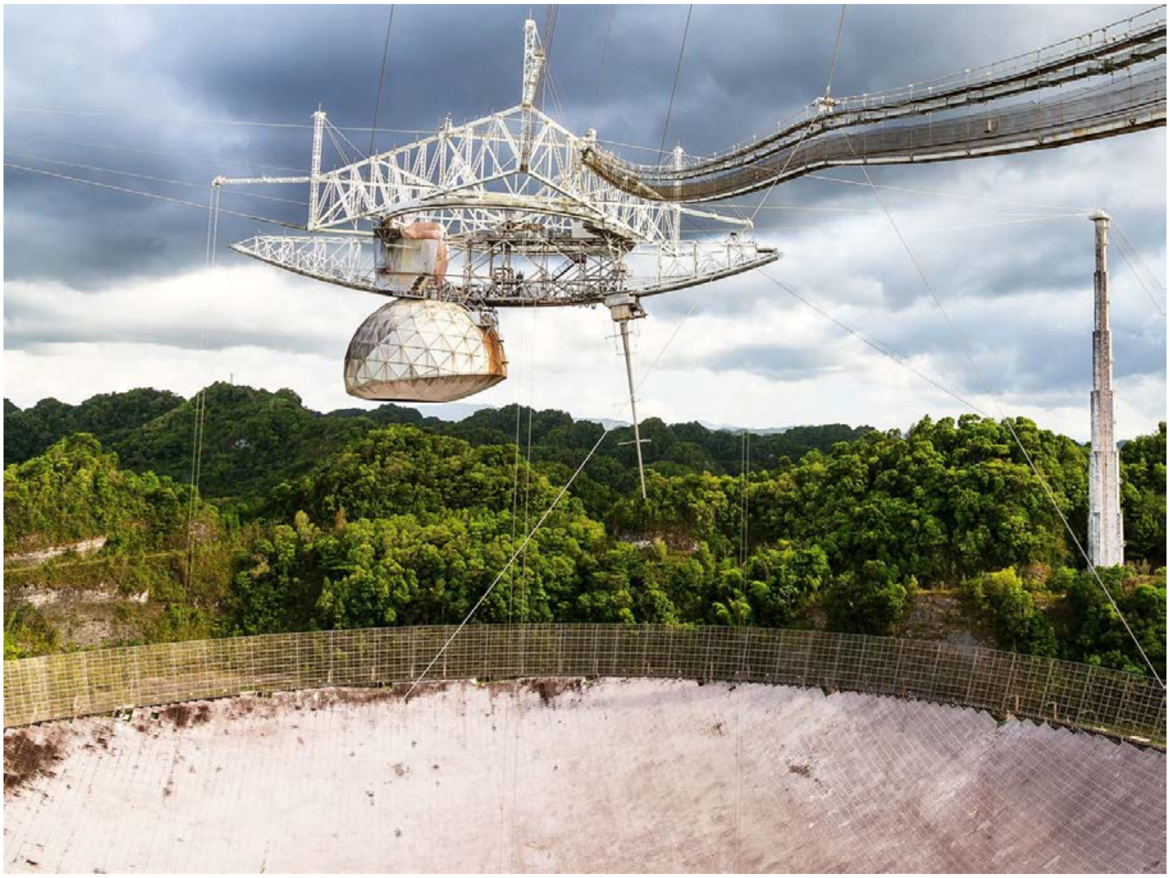
INTRODUCTION



The Arecibo Observatory first opened in 1963 and has been a marvel in engineering ever since. It has been a monumental instrument for scientific research in the fields of astronomy, planetary radar, ionospheric probing and HF heating modification, and optical probing of the atmosphere.

While the science and the discoveries are well known to many, the antenna technology and engineering are equally as impressive as the discoveries. The original concept, by Prof. William Gordon in the Electrical Engineering Department at Cornell University, was for a 1000 foot parabolic dish aiming only at zenith, with no tracking capability for studies of the ionosphere with the newly developed technique of incoherent scatter radar (ISR). Fortunately, knowledge of some on going research with spherical reflectors was suggested where the feed could be moved to slew the beam.

ORIGINAL DESIGN

The original surface in the karst sinkhole at Arecibo was made out of a chicken wire type of mesh and limited the response to below 600 MHz. A 2.5 MW 430 MHz pulse radar transmitter was built for the ISR using a pair of klystrons, and the power was delivered with some 1500 feet of WR-2100 waveguide (loss of 1.25 dB at 430 MHz) to the feed supported from a huge platform above the dish and three tall concrete towers. The feed was attached to a small building called a carriage house that moved along an arc shaped azimuth arm that rotated along a huge circular track. A very unique rotary joint was in the center where the power would transfer through. A movable collector on rollers was fed through a slot in the bottom of the curved WG along the azimuth arm and served to convey RF from the 430 MHz transmitter to the line feed while minimizing reflections. A turnstile was inside the carriage house to feed the waveguide modes to produce circular polarization from the feed.   With a spherical reflector, the rays focus along a line instead of at a single point, as in a parabolic dish.

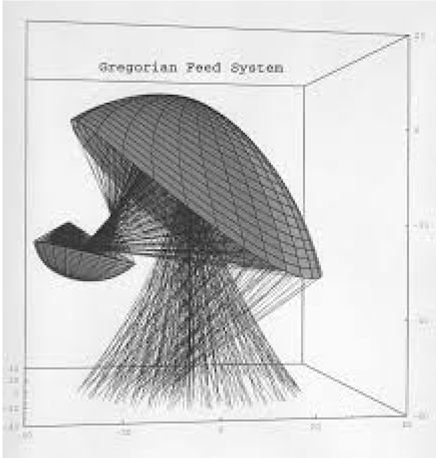
LINEFEEDS

Many line feeds were designed for various frequencies mainly from rectangular and square waveguides with many slots as the radiators. In the early 1970s, Allan Love designed a circular waveguide feed with 6 circumferential slot radiators around the waveguide and then many of these along the total 96 foot long line feed for the 430 MHz system. This yielded a large improvement in aperture efficiency of some 70% and a final gain of 61 dBi at 430 MHz. At the same time in the early 1970s, with a first upgrade, the chicken wire surface was replaced with 38,788 3 by 6 foot panels with small holes to let sunlight come through to prevent erosion with needed plant life growing underneath the dish. A photogrammetry system was used to align the dish to a 2.5mm RMS error that allowed operation to 10 GHz.

GREGORIAN UPGRADE

A second upgrade was carried out in the 1990s when Per-Simon Kildal and others designed a Gregorian dual reflector system that was enclosed in an 86 foot diameter protective dome. This allowed a rotating floor of different point feed horns to be moved into a single focus thus correcting the spherical aberration and not being limited by the narrow bandwidth of line feeds.

All of the cooled receiving electronics were in this dome as well as a S-Band 1 MW CW transmitter for planetary radar. There also was a 430 MHz horn for the ISR, and the power could be split between this horn and the 430 MHz line feed for dual beam experiments in the ionosphere to measure winds and structures. Also, a 50 foot high ground screen reflector was installed around the perimeter of the dish to reduce ground temperature noise into the receive systems.



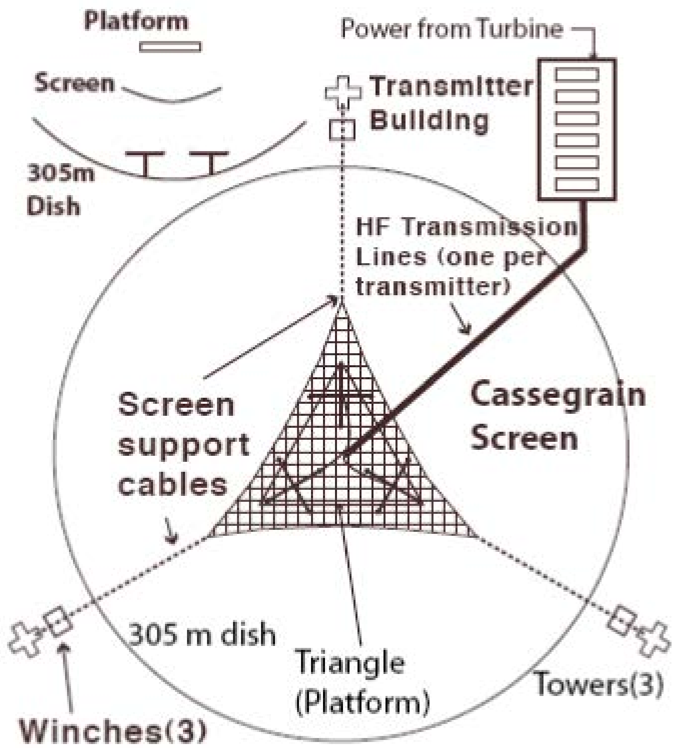
[VIDEO] https://www.youtube.com/embed/IqGnnpwEwug?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

IONOSPHERIC HF HEATING

In 1998, the HF heating (ionospheric modification) facility located about 10 km along the coast was destroyed by Hurricane Georges. This facility had a design that consisted of 32 pyramidal log periodic antennas covering 3 to 12 MHz and a power of 600 kW. It was used to modify the ionosphere effectively creating a plasma research laboratory in the sky. The 430 MHz ISR was then used as a diagnostic tool to measure the effects of the ionospheric heating.

It was decided to not rebuild another big phased array away from the dish and then to use the dish, if possible, for this purpose. Several designs were considered, including a single large Yagi, but, in the end, the best design was a Cassegrain system with a 300 foot diameter mesh that formed a frequency selective surface (FSS) to reflect 5 MHz, but be transparent to 300 MHz and higher.

This mesh was supported from the 3 huge concrete towers that held up the platform, and the mesh could be raised and lowered with winches. A triangular crossed-dipole array at both 5.1 and 8.175 MHz was constructed at the bottom of the dish illuminating the mesh sub-reflector. A transmitter facility was built that powered this HF heating array with six 100 kW transmitters.



I was fortunate enough to work on both of these HF antenna designs, as well as several astronomy feeds during my association with Arecibo for 46 years.

THE COLLAPSE

Most of the 430 MHz 96 foot line feed broke off and fell through the dish in 2017 during Hurricane Maria. In August and November 2020, cables broke that were holding up the platform. As a result, the National Science Foundation (NSF) decided it was better to then decommission Arecibo Observatory's dish as the damage had made the facility too dangerous to repair. Then in December 2020, the platform fell into the dish, destroying large sections of the dish and the equipment in the platform. NSF is presently considering the future of Arecibo Observatory.

The dish after platform collapse in 2020. (Source: Carlos M. Pérez Arbelo, Arecibo Observatory; used with permission.)

Further views of the collapsed dish surface in 2020. (Source: Carlos M. Pérez Arbelo, Arecibo Observatory; used with permission.)

There is so much more to tell about the engineering at Arecibo