5.9A THE ARECIBO OBSERVATORY AS AN MST RADAR

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The radars and other systems at the Arecibo Observatory were designed and built, originally, for incoherent-scatter and radio-astronomy research. More recently, important additions have been made for planetary radar and artificial RF heating of the ionosphere. Although designed and built for a different application, these systems have shown to be very powerful tools for tropospheric, stratospheric and mesospheric research. The Observatory at present has two main radars: one at 430 and the other at 2380 MHz. In addition, 50-MHz MST radar work has been done using portable transmitters brought to the Observatory for this purpose. This capability will become permanent with the recent acquisition of a transmitter at this frequency. Furthermore, control and data processing systems have been developed to use the powerful HF transmitter and antennas of the HF-heating facility as an HF-bistatic radar.

The present paper will make a brief description of the four radars available at the Observatory. We have included in the bibliography a list of references where more detailed descriptions of these systems can be found. The list also includes papers of scientific nature which further illustrate the capabilities of the Arecibo Observatory as an MST radar. We will not cover the capabilities of the observatory for mesospheric research using incoherent scatter techniques. These capabilities have been recently reviewed by MATHEWS [1981, 1984].

THE 430-MHz RADAR

The 430-MHz Arecibo radar in its ST mode configuration has been described by WOODMAN (1980a). Some recent improvements are described by WOODMAN et al. (1979) and SULZER and WOODMAN (1983). A block diagram of this configuration is shown in Figure 1. The most outstanding characteristics of the system are its large power-aperture product, a very powerful processing system and a very flexible radar control.

The transmitter has 2 MW of maximum power at a 6% maximum duty cycle. Its phase-coding bandwidth permits a minimum code length of 1 μsec which corresponds to a maximum altitude resolution of 150 meters.

The antenna is the largest reflection antenna in the world. The reflector is spherical with a diameter of 300 meters. Steering is performed by moving the position of the feed point. The feed illuminates the reflector almost evenly. It can point in any direction within 20° of zenith. Control is commanded by the central control and processing computer. Beam width at MST altitudes is cylindrical, since these altitudes are in the nearfield of the antenna. The effective beam width is sufficiently narrow to produce negligible effects on the altitude resolution or beam width broadening of the spectral width.

Receiving performance is determined by the noise level of the front end. System temperature is of the order of 100° K. Receiver bandwidth is selectable at both, the IF (30 MHz) and dc level. Gaussian-shaped filters of different bandwidths can be patched at IF frequency, and square-shaped pulse filters at the coherently detected level.

The control and processing system works around a central Harris/6 mini-

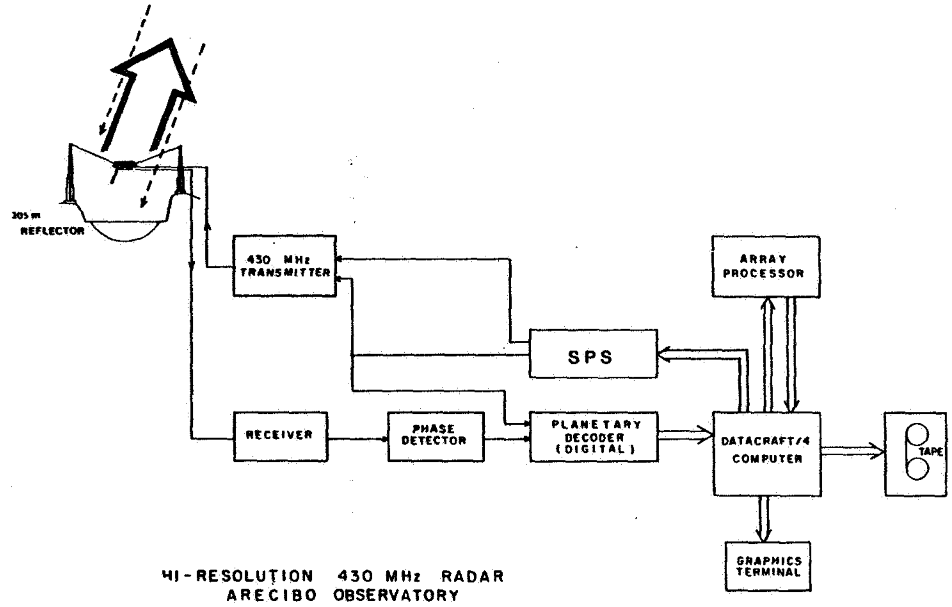


Figure 1.

computer. But, the flexibility and processing capabilities of the system are mainly determined by a special purpose controller, a powerful decoder and an array processor.

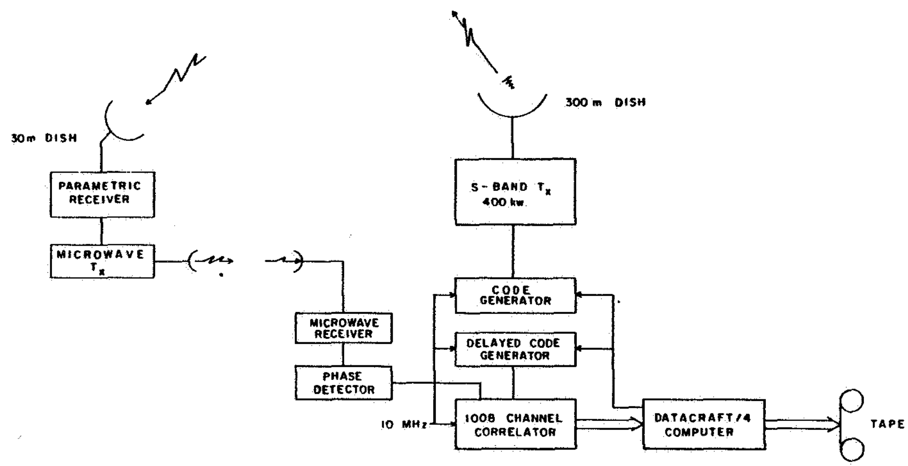
Control pulses for the radar to the ADC and the decoder, including the code sequences, are generated by a Synchronous Programmable Sequencer (SPS) (WOODMAN et al., 1979). This sequence can generate 16 independent, TTL level, arbitrary sequences with arbitrary length and transition resolution of 0.1 μsec. It is capable, for instance, of clutter which makes the evaluation of vertical velocities difficult.

THE 2380-MHz BISTATIC RADAR

The S-band 2380 radar was built for planetary radar research, but it has been adapted for stratospheric research in a bistatic mode. The system techniques and capabilities is described in detail by WOODMAN (1980b). Here we will limit ourselves to a short description underlining its more important features and limitations.

A block diagram of the system is depicted in Figure 2. The transmitter is the most powerful radar presently in use for MST applications. It transmits continuously 500 kW of average power. The transmitter does not have a transmit-receive switch, hence the need for a bistatic approach. It uses the 300-meter-diameter spherical reflector as a transmission antenna and a 30-meter parabolic at Higuiales, 11 km north of the Observatory, for reception. The receiver has a low-noise parametric receiver, with a 25° K system temperature. The received signal is sent back to the Observatory via a wide band telemetry link for processing.

At any one time scattered signals are received mainly from turbulent fluctuations within the common volume defined by the intersection of both antennas. One of the outstanding features of this system is its high altitude resolution. Resolutions as small as 30 meters have been obtained. Higher resolution than the size of the common volume is obtained by means of phase-



HI-RESOLUTION S-BAND STRATOSPHERIC SYSTEM
ARECIBO OBSERVATORY

Figure 2.

shift coding. Continuous periodic pseudorandom codes are used with adjustable baud and period length.

Typical values for the above-mentioned resolution are 0.2 μsec baud length with a period of 1023 bauds. Decoding is performed with the Arecibo's 1008 lag correlator, by cross-correlating the real and imaginary components of the coherently detected signal with the transmitter code. The altitude range of observations is from 14 to 19 km. The lower altitude is determined by the geometry of the antennas at maximum zenith angles (20°), and the highest by the sensitivity of the system. Sensitivity at this altitude is apparently determined by the sharp cut-off of the fluctuations k-spectrum at the inner scale, which becomes comparable to the wavelength of the radar at this altitude. The small probing wavelength should also permit the study of the turbulence spectrum shape at ks close to the inner scale.

The original observations gave only power information, because of the slowness of the correlator to dump the decoded profiles to the computer. This has been circumvented recently with a scheme in which two consecutive decoded profiles are dumped at any one time, permitting the evaluation of velocity and spectral width information. A new correlator is being built which will allow the evaluation of full spectral information and greater sensitivity. The sensitivity is improved by reducing the amount of processing idle time.

There is a project to provide the transmitter with a fast transmit receive switch which would allow the use of the radar as a monostatic radar. This will permit the study of lower tropospheric altitudes.

THE MPI-ARECIBO 50-MHz RADAR

During 1980-81 the Max-Planck Institute brought their mobile radar to the Arecibo Observatory (ROTTGER et al., 1983). The system used a self-contained transreceiver, control and processing system and the large 300-meter Arecibo reflector with a specially designed feed for this frequency. This equipment is no longer available to the Observatory. Recently the Observatory has placed an order for a 50-100 kW MHz transmitter, which with existing receivers control and processing system, (Figure 1) including software will allow MST research at these frequencies. The possibility of observing at 3 different frequencies from the same location will be an important capability of the Arecibo Observatory.

THE ARECIBO HF BISTATIC RADAR

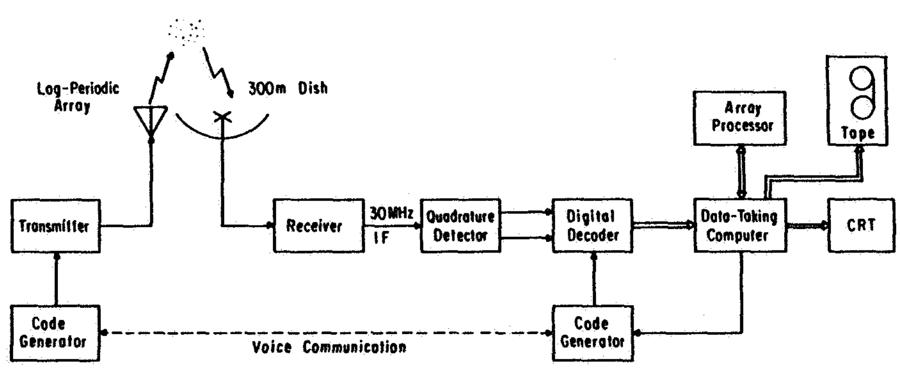
A large antenna and a powerful HF transmitter has been recently constructed north of the Arecibo Observatory for the purpose of artificially heating the ionosphere. The antenna consists of an array of 8 x 16 log-periodic vertically pointing antennas covering an area of 340 x 680 meters. The transmitter has a continuous rating of 800 kW. Both systems have a nominal frequency range of 3 to 12 MHz.

A bistatic radar has been recently implemented (GONZALES and WOODMAN, 1983) for partial-reflection and backscatter studies. The HF-heating facility is used for transmission and the large Arecibo disk for reception. The system uses pulse coding on transmission with a maximum resolution of 8-16 μsec. Coherent addition is performed on reception and full spectrum information is obtained in parallel from "ground wave altitudes" to F-region ionospheric heights (256 altitude). A new coding scheme has been used; it is based on a continuous set of complementary codes which vary from pair to pair. The sequence has the property of cancelling echoes which have been range folded into the altitudes of interest, i.e., only the echoes which belong to the previous pulse contribute to the profile. This is important, since it allows for the cancellation of strong-multiple reflections from the F- and E-region ranges.

A schematic diagram of the system is shown in Figure 3.

The Arecibo HF bistatic radar, because of its power, antenna gain and sophisticated processing is today perhaps the most sensitive HF radar in the world.

(References in this paper are included in the publications listed below.)



Arecibo Observatory
HF Bistatic Radar

Figure 3.

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