The Effects of Water on the Noise-Temperature Contribution of Deep Space Network Microwave Feed Components

M. J. Britcliffe[1] and R. C. Clauss[2]

Large increases in the system operating noise temperature, T_{op}, occur when water collects on Deep Space Network (DSN) antenna and microwave feed-system components. This article describes measurements made at 8.4 GHz (X-band) to assess the effects of water on the critical antenna components. It also describes the measurement results of improvements in performance achieved by the use of techniques or procedures developed to reduce the effects of water on critical components.

I. Introduction

Large increases in the system operating noise temperature, T_{op}, occur when water collects on Deep Space Network (DSN) antenna and microwave feed-system components. Components that add the most noise when wet, or moist, include the feed-horn cover, the dichroic plate, and the perforated antenna panels used on the outer portion of the main reflector. The noise temperature increase caused by water on these components is often higher than the contribution of the rain in the atmosphere. The increase continues to affect the system after the rain at the site has stopped. It can take hours for the water to evaporate. A series of measurements was performed at 8.4 GHz (X-band) to study this problem and to find techniques to reduce the degradation.

Two types of surface coatings were tested on the feed window and dichroic plate. Hydrophobic coatings reduce the adhesion of water on surfaces. A hydrophobic coating reduced the noise contribution of water on the feed window substantially.

The opposite of a hydrophobic treatment is a hydrophilic one. Hydrophilic treatments increase the adhesion of water. A hydrophilic coating reduced the noise contribution of wet dichroic plates.

II. Test Configuration

A high-electron-mobility transistor (HEMT) low-noise amplifier (LNA), a corrugated feed horn with 22-dB gain configured for right circular polarization, and a DSN Pyle-hole-type dichroic plate were

---

[1] Communications Ground Systems Section.

[2] Spacecraft Telecommunications Equipment Section.

The research described in this publication was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

mounted on a movable platform as they would be installed on the antenna. The configuration allowed testing of the effects of water on the feed-system components at different elevation angles. The zenith total system operating temperature, T_{op}, for the feed/LNA system was 26 K. The outdoor test setup is shown in Fig. 1. The output of the LNA was connected to a total-power radiometer with 0.1 K resolution. The radiometer automatically measured, recorded, and displayed T_{op}.

Fig. 1. The test setup on the roof.

III. Water on Feed-Horn Windows and Hydrophobic Coatings

Water collecting on feed-horn windows of Cassegrain antennas is a known problem. DSN feed horns are typically covered with a thin film window made of Kapton. A 10-mm-diameter drop of water at the center of a 22-dB feed horn caused a 40-K increase in noise temperature. Water on the feed window can be the result of either rain directly on the window or from dripping from water collected in the subreflector when the antenna is at zenith. The noise-temperature degradation is affected by the condition (age) of the Kapton film. As the Kapton ages, the surface oxidizes and tends to retain more water.

There are several types of surface coatings designed to prevent the accumulation of water on components. Hydrophobic coatings are designed to reduce the adhesion of water on surfaces. Rainex is a commercially available product designed to improve visibility through wet automotive glass. Rainex is silicone oil dissolved in alcohol. A series of tests was performed to study the compatibility of Rainex on Kapton horn windows by the Mechanical Engineering Section at JPL. The life and performance of Kapton is unaffected by Rainex. Figure 2 shows the measured noise contribution of water on the feed window with and without Rainex hydrophobic coating. The wet horn window contributed 35 to 90 K. Rainex reduced the contribution from 90 K at zenith to 9 K. Treating the window with Rainex had no measurable effect on the dry T_{op} of the system. Replacing the Kapton regularly and treating the window with a hydrophobic coating can minimize the feed-window problem.

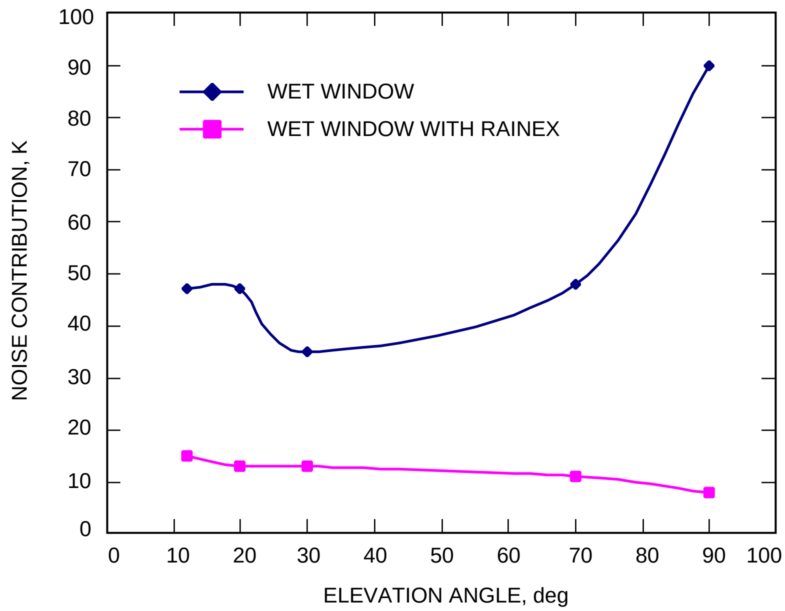

Fig. 2. Noise-temperature contribution of the feed-window coating.

There are new manufacturers of hydrophobic coatings designed specifically for microwave antenna applications. Vellox, Cytonix, and Prodelin all make hydrophobic coatings for antennas and radomes.

IV. Water on Dichroic Plates and Hydrophilic Coatings

Dichroic-plate-type frequency-selective surfaces are used to separate 2.3-GHz (S-band) and 8.4-GHz (X-band) signals to achieve simultaneous S-/X-band operation. On Cassegrain antennas, the dichroic plates are mounted above the feed horns and are subjected to rain. The rain collects on the surface of the plate and in the waveguide holes and causes noise-temperature degradation.

Unfortunately, hydrophobic coatings did not improve the performance of wet dichroic plates. Applying Rainex to the dichroic plate hole actually increases the T_{op} at higher elevation angles. The hydrophobic coating causes the water to bead up higher in the waveguides.

A hydrophilic coating that tends to make the water cling closer to the surface was tested on a dichroic plate. Detergent is a hydrophilic coating. Anti-fog used in diving masks is another example. The dichroic plate was tested wet after being coated with a thin layer of liquid detergent. The detergent coating lowered the noise contribution of the wet plate substantially. The noise contribution of the dichroic plate wet, with Rainex, and with detergent is shown in Fig. 3. The wet dichroic plate contributed from 10 to 44 K. Detergent on the plate reduced the contribution from 32 to 6 K at zenith.

Unfortunately, the soap film has a short life. No acceptable hydrophilic coating has been identified. There are several manufacturers of hydrophilic coatings used to reduce drag on racing sailboats that might be useful for this application. New types of long-life hydrophilic coatings should be investigated.

V. Water on Antenna-Dish Panels

The noise-temperature degradation caused by water on antenna panels at 8.4 GHz was studied by Otoshi and Franco [1]. The effect is largely due to water collecting in panel perforations. The results of

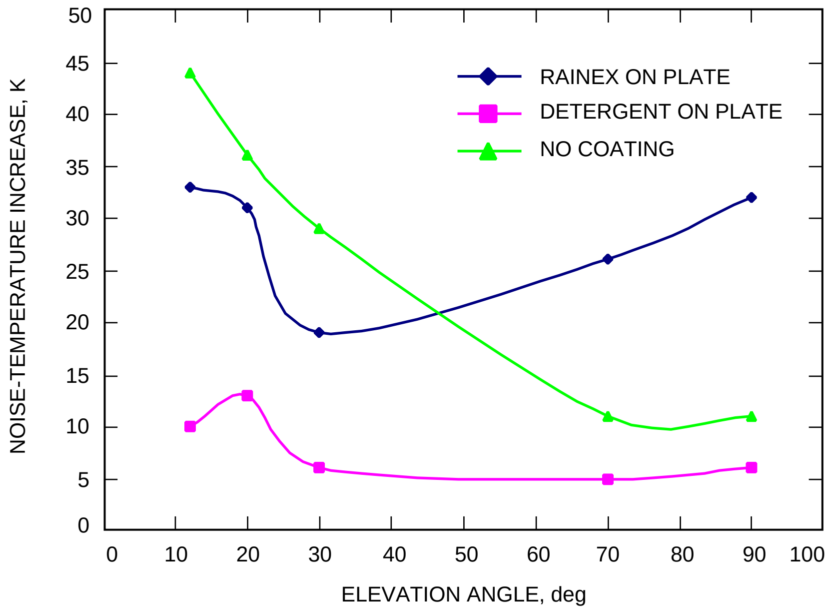

Fig. 3. Noise contribution of the wet dichroic plate.

measurements made on painted perforated panels similar to those used on DSN antennas showed that the increase due to water can be as high as 9 K. Tests performed on solid panels showed only a 1.2-K increase.

VI. Water on Flat Reflecting Surfaces

The noise contribution of water on smooth metal reflectors like beam-waveguide (BWG) mirrors is small. Otoshi and Franco tested unpainted aluminum panels wet. The measurements show only a 1.2-K increase. This was verified during the roof testing. A flat metal plate simulating a BWG mirror was placed in front of the feed. Figure 4 shows the mirror being tested with water flowing over the surface. The water on the plate resulted in only a 1-K increase.

VII. Rain Blowers in Conjunction with Hydrophobic Coatings

Combining a hydrophobic coating with a blower is the best system for removing water from feed components. The airflow has two effects. The airflow blows large droplets off the surface and evaporates smaller droplets. Current DSN blowers are fairly low velocity.

A high-velocity horn blower was demonstrated using compressed air and small nozzles around the horn window; it was very effective in removing water quickly. A 6-mm-diameter tube with 1.5-mm-diameter perforations that direct air to the center of the feed window was attached to the feed flange. A single 6-mm line supplied compressed air at 4 mPa. The high-velocity blower could dry a horn cover saturated with water in one second. The use of a high-velocity blower on the dichroic plate should be investigated.

VIII. Conclusion and Recommendations

The hydrophobic coating Rainex combined with a blower solves the problem of water on feed-horn windows. A hydrophobic coating alone did not help on the dichroic plate. A hydrophilic coating on the plate substantially reduced the noise contribution. Unfortunately, no suitable hydrophilic coating is known at this time. Although the hydrophobic coating alone does not solve the dichroic problem,

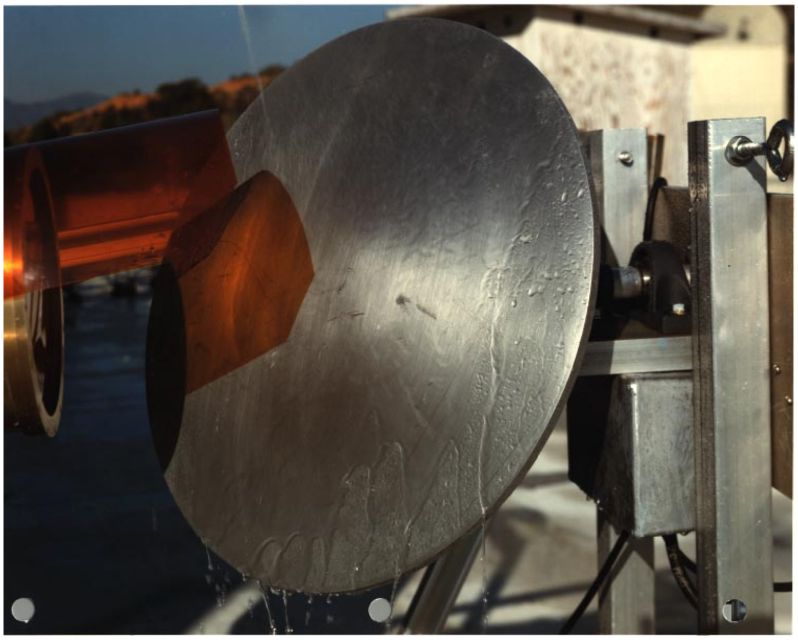

Fig. 4. Test of water on a flat aluminum reflector.

the combination of using a high-velocity blower on the dichroic plate and a hydrophobic coating should be investigated. More work should be done to test the effect of a hydrophobic coating on the dichroic plate and to identify any other suitable coatings. Wet perforated antenna panels are also contributors to noise temperature. The problem will be exaggerated at 32 GHz. The requirement for perforated antenna panels on new antennas should be reviewed and eliminated if possible.

Reference

[1] T. Y. Otoshi and M. M. Franco, "Radiometric Tests on Wet and Dry Antenna Reflector Surface Panels," *The Telecommunications and Data Acquisition Progress Report 42-100, October–December 1989*, Jet Propulsion Laboratory, Pasadena, California, pp. 111–130, February 15, 1990.
http://tmo.jpl.nasa.gov/tmo/progress_report/42-100/100J.PDF