

Thermal Measurements of Microwave Transmitter Feedhorn Window

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Thermal measurements of microwave transmitter feedhorn windows were performed using an imaging infrared radiometer. The measurement technique is described and results are presented for windows made of 0.001-in. Kapton (trademark of Dupont Chemical Co.) and 0.1-in. HTP-6 (Space Shuttle tile material). Measured and calculated temperatures agree well.

I. Introduction

The use of a nonpermeable cover is required on microwave transmitter feedhorns to prevent rainwater and wind-borne debris from entering the transmitter waveguide. This window must be manufactured of a low-loss material to minimize heating of the window due to the passing Radio Frequency (RF) beam. In addition, the window material must tolerate high temperatures without permanent damage. Heating of the window is caused both by dielectric heating due to the RF beam and by the burning of debris resting on the window surface.

Present transmitters operating at 8.5 GHz employ a Kapton (trademark of Dupont Chemical Co.) window at power levels up to 400 kW. Performance of the Kapton window is adequate, with some failures due to debris burning on the window (insects or oil droplets). Future transmitters at this frequency will be capable of output power levels of 1 MW [1].

Since no temperature data were available for Kapton windows operating at 400 kW, this information was needed to predict the suitability of using a Kapton window at 1 MW. Based on data obtained for Kapton, the use of alternate

window material may be required. Other possible choices include fused quartz and sapphire. Another promising material is High Thermal Performance (HTP), developed by Lockheed and used on the Space Shuttle for heat shield insulation. This material possesses excellent thermal and electrical properties for this application (see Table 1). In order to investigate the actual performance of HTP under the action of intense RF beams, a 0.1-in. thick window was fabricated from HPT-6 (6 lb/ft³).

II. Method

It is exceedingly difficult to make direct temperature measurements of a microwave transmitter feedhorn window. The use of thermocouples and other means of electrical thermometry is not possible due to rapid and intense heating of any metal in the path of the RF beam. Direct viewing of the window by infrared imaging equipment is also not a viable method, as almost any direct optical path to the window will also be in the RF beam path, possibly damaging the instrument, even if remotely controlled. RF reflections from metal on a

measuring instrument could also be potentially harmful to personnel nearby.

In order to overcome these difficulties, a highly-reflective infrared mirror was erected on a nonmetallic stand parallel to the feedhorn, 14 feet away, at an angle of 45 degrees (see Fig. 1). The mirror was fabricated from a 16-in. by 16-in. by 1-in.-thick soda lime float-glass blank with a highly-reflective gold finish electrodeposited on one side. An Inframetrics 600 infrared radiometer with a 3X telescope lens was placed 54 feet away, allowing viewing of the feedhorn window image on the mirror (see Fig. 2). To ensure the safety of the radiometer operator, the power density was calculated in the vicinity of the radiometer assuming reflection from the mirror surface. Using a worst-case analysis, at no time was a power density greater than 1 mW/cm^2 calculated. In addition, during the performance of the test, a Narda radiation monitor was used to constantly survey the area about the radiometer.

Calibration of the radiometer was accomplished by setting a large tub of hot water on the transmitter window (with no RF present). A metal can, painted flat black, was placed in the water to serve as a black body radiator, and a mercury thermometer was immersed in the water. After calibration, agreement of better than 1 degree C was obtained between the temperature indication of the radiometer and the true water temperature as measured by the mercury thermometer.¹

Measurements of both peak temperature and the temperature profile across the face of the window were then performed for both Kapton and HPT-6 for transmitted power levels in the range of 200–365 kW.

III. Results

The highest temperature observed using the Kapton window was approximately 100 degrees C at a power level of

¹For a more detailed explanation of the radiometer usage and calibration, see S. Glazer, "Thermal Infrared Measurements of R. F. Transmitter Feedhorn Windows During High Power Transmitting Operation," *JPL IOM 3547-TSE-109* (internal document), June 1988.

360 kW. However, due to 45-degree F air temperature with winds gusting at 30 – 35 mi/hr and the very low thermal mass of the 0.001-in. Kapton window, it was not possible to obtain an accurate representation of the typical operating conditions. A retest in the future under calm conditions is required to properly evaluate the performance of the Kapton window.

More stable temperature data were obtained for the HTP-6 window. A peak operating temperature of 475 degrees C was observed at 365-kW transmitted power. The power-temperature relationship for HTP-6 is shown in Fig. 3. Simple calculations were made of the temperature of a 0.1-in. HTP-6 window at 365 kW using two different models. Assuming a uniformly heated disk model, a temperature of 270 degrees C was predicted. Using a model of a Gaussian temperature distribution over the disk, a temperature of 580 degrees C was predicted. Given the Gaussian distribution of the RF beam passing through the window (see Fig. 4), the second estimate was the better one. The lower measured temperature value was due to neglecting conductive cooling through the window mounting surface in the calculations.

As of April 1989, testing using the X-band radiometer of the Radio Frequency and Microwave Subsystems Section produced values for the noise temperature contribution and insertion loss of the 0.1-inch thick HTP-6 feedhorn window. These values are 0.2 Kelvin and 0.003 dB. This measurement was performed by M. Britcliffe.

IV. Conclusion

A high-power microwave transmitter feedhorn window was successfully imaged using an infrared radiometer-mirror technique. Agreement between the measured and actual temperature of a body was excellent with this method, which is also useful in other remote thermal imaging applications. Good data were not taken for a 0.001-in. thick Kapton window due to the weather conditions. A reevaluation of the Kapton window needs to be performed under better conditions. Measurements of low-loss quartz and lower-density HTP windows would also be of interest.

Acknowledgments

Special thanks are due to Stuart Glazer for the capable operation of the infrared radiometer and the determination of the infrared radiation characteristics of Kapton and HTP-6. E. W. Stone is also to be thanked for suggesting the evaluation of HTP-6.

Reference

- [1] A. M. Bhanji, D. J. Hoppe, D. L. Conroy, and A. J. Freiley, "Conceptual Design of a 1-MW CW X-Band Transmitter for Planetary Radar," *TDA Progress Report 42-95*, vol. July-September 1988, Jet Propulsion Laboratory, Pasadena, California, pp. 97-111, November 15, 1988.

Table 1. Some physical properties of HTP-6

Density	6 lb/ft ³
Dielectric constant	1.07
Loss tangent	0.0005
Maximum operating temperature	980 degrees C

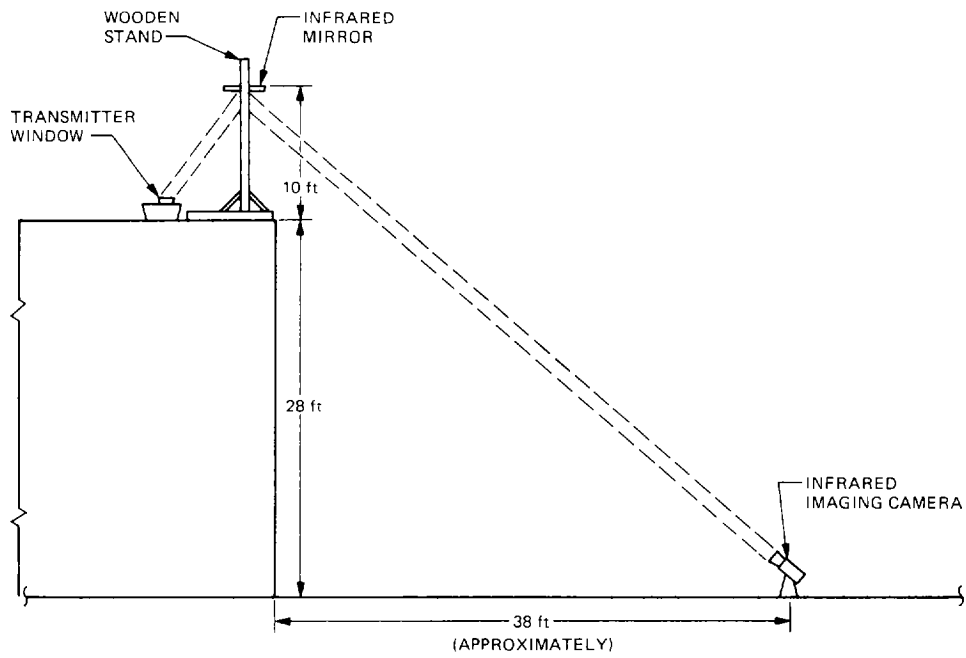


Fig. 1. Microwave window infrared imaging test configuration.

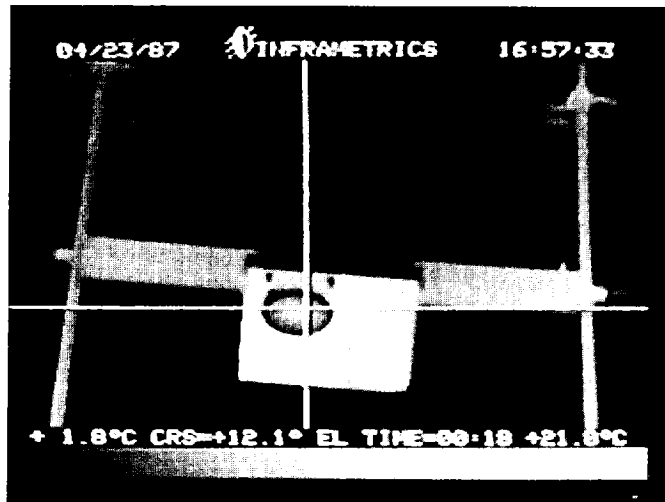


Fig. 2. Infrared image of window in mirror.

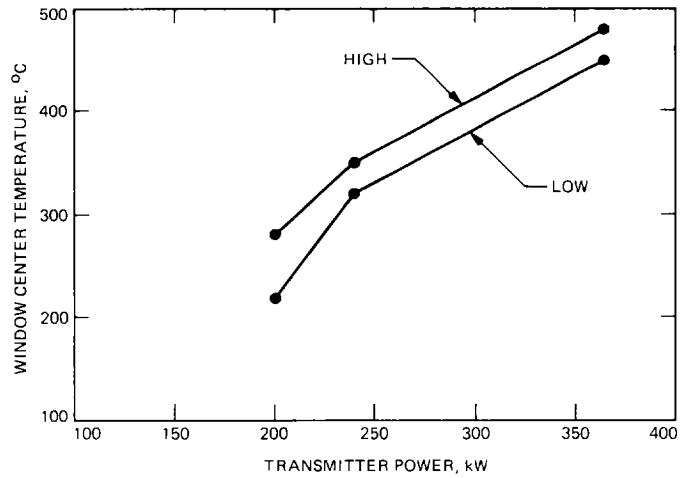


Fig. 3. HTP-6 window temperature versus transmitted power.

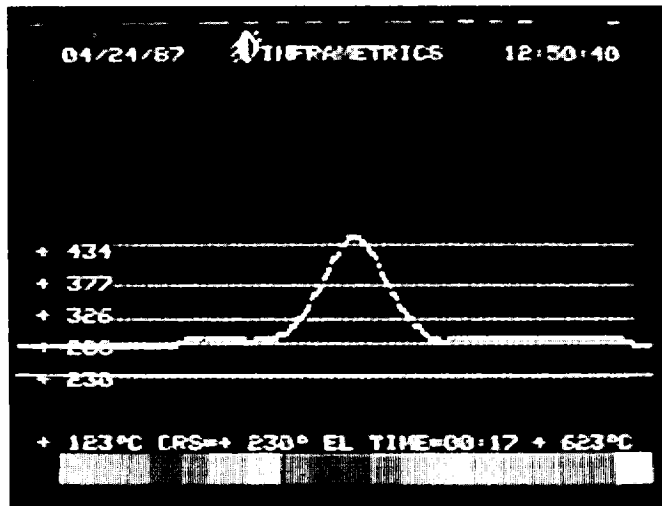


Fig. 4. Temperature distribution across window surface.