Aerodynamic Static Differential Pressure Values for the 50 Percent Porous Reflector Dish

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Although the solid and the 25 percent porous thin paraboloidal dishes were instrumented with static pressure tubes and tested in the wind tunnel, the porosity used for the 64-m antenna was 50 percent for economic reasons. The extrapolation to 50 percent porosity, to date, has resulted in conservative values. This report describes a method of extrapolating from the available data the 50 percent porous pressure coefficient differences. The method is verified by checking the available wind tunnel static pressure data against the force data.

I. Introduction

A series of antenna models were tested in a wind tunnel (Refs. 1 and 2) to provide wind loading data for the design of the 64-meter antenna. The parameters of the models were selected on the basis of preliminary design results. For example, the complete antenna model used a 25 percent porous reflector surface for the outer 25 percent radius. However, reflectors with solid, 25 percent porous, and 50 percent porous dishes were tested for their aerodynamic force and moment values. Only the solid and the 25 percent porous dishes were tested for the static pressure values used primarily to determine the wind loading on the reflector's surface panels. The wind loading was then applied to the reflector structural models to determine the rms distortions from a paraboloidal shape, which is useful for radio frequency (RF) gain calculations.

As part of the cost reduction effort, the porosity of the dish was increased to 50 percent in the final design so that lower wind designing loads could be used. This caused the generation, by interpolation and extrapolation, of applicable force and moment curves for the whole antenna under wind loading. New curves for the static pressure values were also generated. The results, available to date (Ref. 1), show that the force and moment curves were accurate. However, the static pressure curves used for the design proved to be too conservative.

This report describes a method for extrapolating the 50 percent porous static pressure data from the solid and the 25 percent porous static pressure values. The accuracy of the result (estimated within 10 percent) should be well within the requirements for structural analysis.

The verification of the calculating method was proved by first applying it to available solid dish and 25 percent porous dish static wind tunnel pressure data. The answers resulted in a good match between the wind tunnel force and moment test values and the integrated values of the static pressures. Since force and moment values for the 50 percent porous dish from the wind tunnel tests are available, correctly extrapolated static pressure for the 50 percent porous dish, when integrated, should match the wind tunnel values.

II. Description

The static pressure values were described in Ref. 2 as pressure coefficient differences across a thin paraboloidal surface with a focal length-to-diameter (F/D) value of 0.33. An example is Fig. 1 with the average pressure coefficient difference values shown for the 25 percent porous dish by a solid curve, where the pitch angle is equal to 180 degrees and the yaw angle equal to zero. In other words, the wind is blowing along the symmetric axis of the dish into the convex side. The solid curve represents the average of the static pressure readings of the pressure tap locations shown in Fig. 2.

Working toward the solution of the static pressure values for the 50 percent porous dishes, static pressure orifices located on a sample porous plate were tested by the Thermophysics and Fluid Dynamics Section in a small wind tunnel available at JPL. The results showed that the static pressure accurately measures the pressure differences across the 50 percent porous plate placed in a wind stream.

Figure 1 shows that the pressure difference coefficient values are higher for the 25 percent porous dish than for the solid. It follows that these values could be higher by the same increment for the 50 percent porous dish as shown by the extrapolated dotted line.

To test the accuracy of the static coefficient differences, as applied to the surface panels of a reflector dish, the static pressure data were interpolated for the pitch angle of 120 degrees by use of curves shown in Fig. 3. The sample values for the 15-degree angle row of static orifices are shown in Fig. 4, where only the windward-half values from one column of static orifices are shown. The other half of the dish was very lightly loaded for porous dishes at a pitch angle of 120 degrees.

The pitch angle of 120 degrees was selected since the pitching moment is the maximum. Also, since the pressure differences have the largest asymmetry at this pitch angle, the reflector distortion should also be the maximum.

A computer program was coded to calculate the solid surface areas applicable to each pressure coefficient difference, followed by integration of the forces with final calculations of the aerodynamic-type coefficients.

In Table 1, the wind tunnel test values (Ref. 1) for the forces and moments are compared with the values computed from the static pressure data from the wind tunnel test values (Ref. 2) for the solid and the 25 percent porous dishes, as well as for the extrapolated curves for the 50 percent porous dish.

III. Conclusions

The drag coefficients for the wind directly into the front and back of the solid and 25 percent porous dishes between the wind tunnel force tests and the integration of the static data compare very closely as presently computed. Of course, this check was also made during the wind tunnel tests for data verification purposes. This match now also serves to check our computer program and the calculations for the 50 percent porous data.

The extrapolated 50 percent porous curve need only be increased slightly in Fig. 1 for a good match of data.

For the 120-degree pitch angle case, the values for axial (body axis) force and the pitching moment coefficients match closely. The normal force coefficient from the static pressure data is substantially smaller. The major part of the difference may be explained as follows: As the direction of this component is normal to the symmetric axis of the reflector, there is a wind force existing in the wind tunnel models not present in the static pressure integrating computations. This wind force arises from the wind hitting the sides of the 9.5-mm (3/8-in.) holes in the 3-mm (1/8-in.)-thick dish plate, and is referred to as shear force or skin friction force.

The axial force coefficients for the solid dishes from the two methods show some difference, which is still not understood at this time.

It is concluded that the extrapolated curves for the 50 percent porous dish will produce accurate aerodynamic coefficient values for paraboloidal dishes of this porosity in the wind.

Acknowledgment

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References

1. Fox, N. L., and Dayman, B., Jr., *Preliminary Report on Paraboloidal Reflector Antenna Wind Tunnel Tests*, IM CP-3, Feb. 28, 1962 (JPL internal document).

2. Fox, N. L., *Load Distributions on the Surface of Paraboloidal Reflector Antennas*, IM CP-4, Feb. 28, 1962 (JPL internal document).

3. Katow, M. S., and McGinness, H. D., "Wind Load Predictions for the 64-meter-diameter Antenna," in *The Deep Space Network Progress Report,* Technical Report 32-1526, Vol. XV, pp. 96–101, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1973.

Table 1. Aerodynamic coefficients of thin paraboloidal dishes

Configuration	Pitch = 0° Yaw = 0°	Pitch = 0° Yaw = 180°	Pitch = 60°; Yaw = 180°		
	C_{AXIAL}	C_{AXIAL}	C_{AXIAL}	C_{NORMAL}	C_{MOMENT}
Solid					
A	1.50	−1.02	−0.187	0.195	0.127
B	1.52	−1.05	−0.280	0.166	0.129
25% porous					
A	1.17	−0.94	−0.321	0.203	0.109
B	1.30	−0.96	−0.349	0.149	0.116
50% porous					
A	0.83	−0.83	−0.294	0.217	0.093
B		−0.77	−0.293	0.125	0.097

F/D = 0.33; moment center at paraboloid's vertex

A = values from wind tunnel's force data

B = values from pressure coefficient difference integration

C_{AXIAL}, C_{NORMAL}, C_{MOMENT} = body axis force and moment coefficients

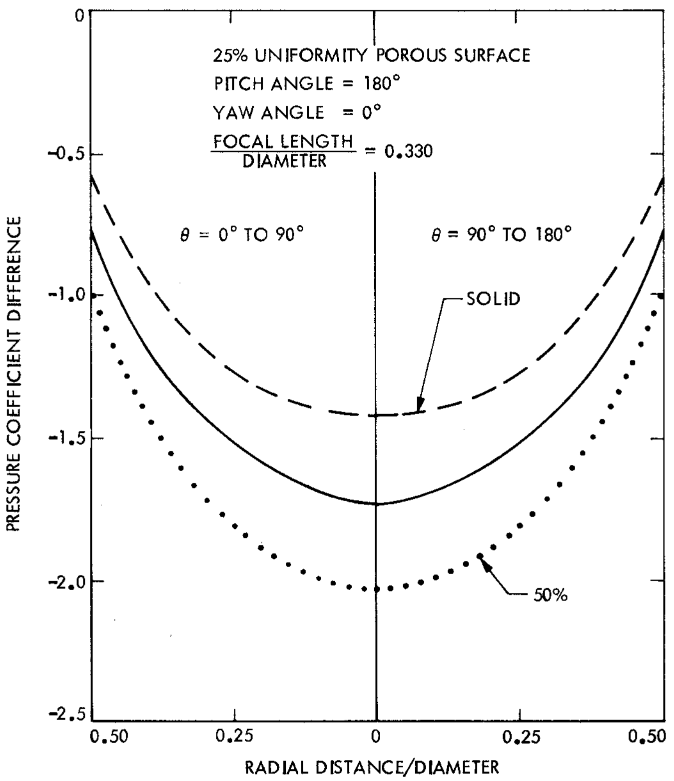

Fig. 1. Pressure coefficient differences across a thin paraboloidal 25 percent uniformly porous surface at pitch angle of 180 deg

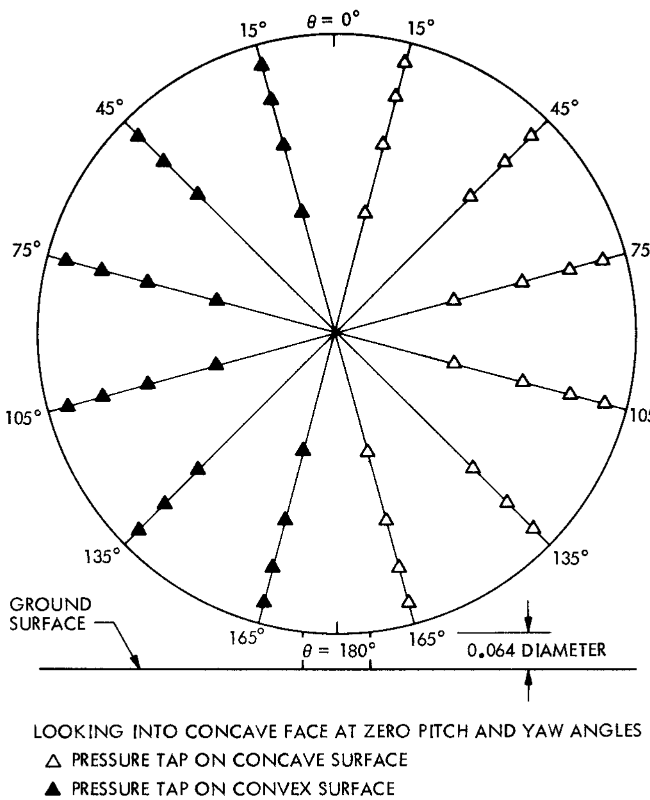

Fig. 2. Pressure tap locations on model

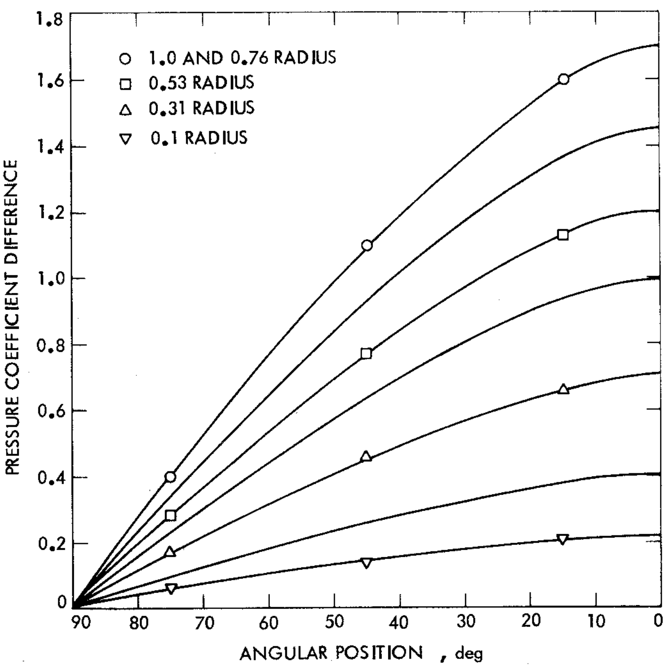

Fig. 3. Pressure coefficient difference: interpolated values

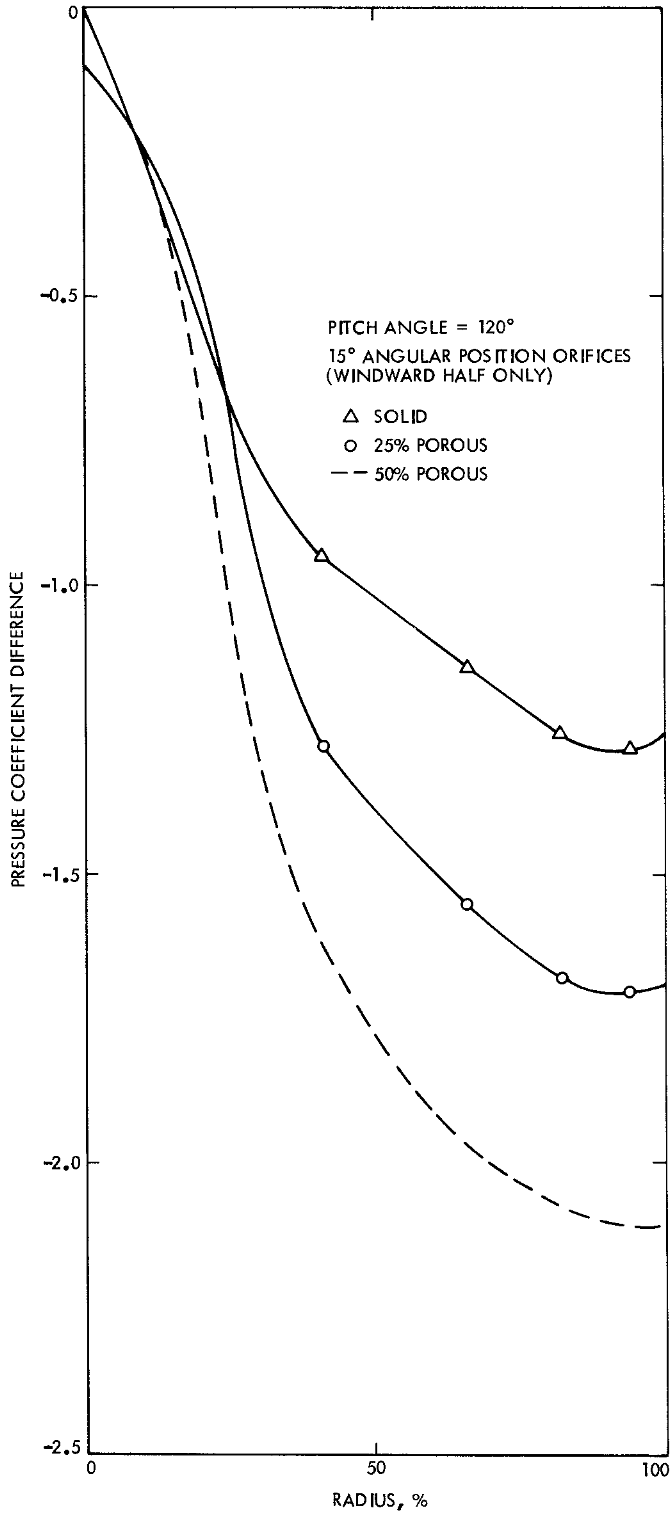

Fig. 4. Pressure coefficient difference at pitch angle of 120 deg