ANTENNA TECHNOLOGY - ANTENNA DESIGN AND SCALE MODEL TECHNIQUES

W. F. Croswell

NASA-Langley Research Center
Hampton, Virginia

ANTENNA DESIGN AND SCALE MODEL TECHNIQUES

OBJECTIVE: TO DEVELOP PROTOTYPE ANTENNA DESIGNS AND METHODS OF MEASURING AND PREDICTING ANTENNA CHARACTERISTICS WHEN MOUNTED ON LARGE COMPLEX SHAPES SUCH AS SPACE SHUTTLE.

APPROACH:

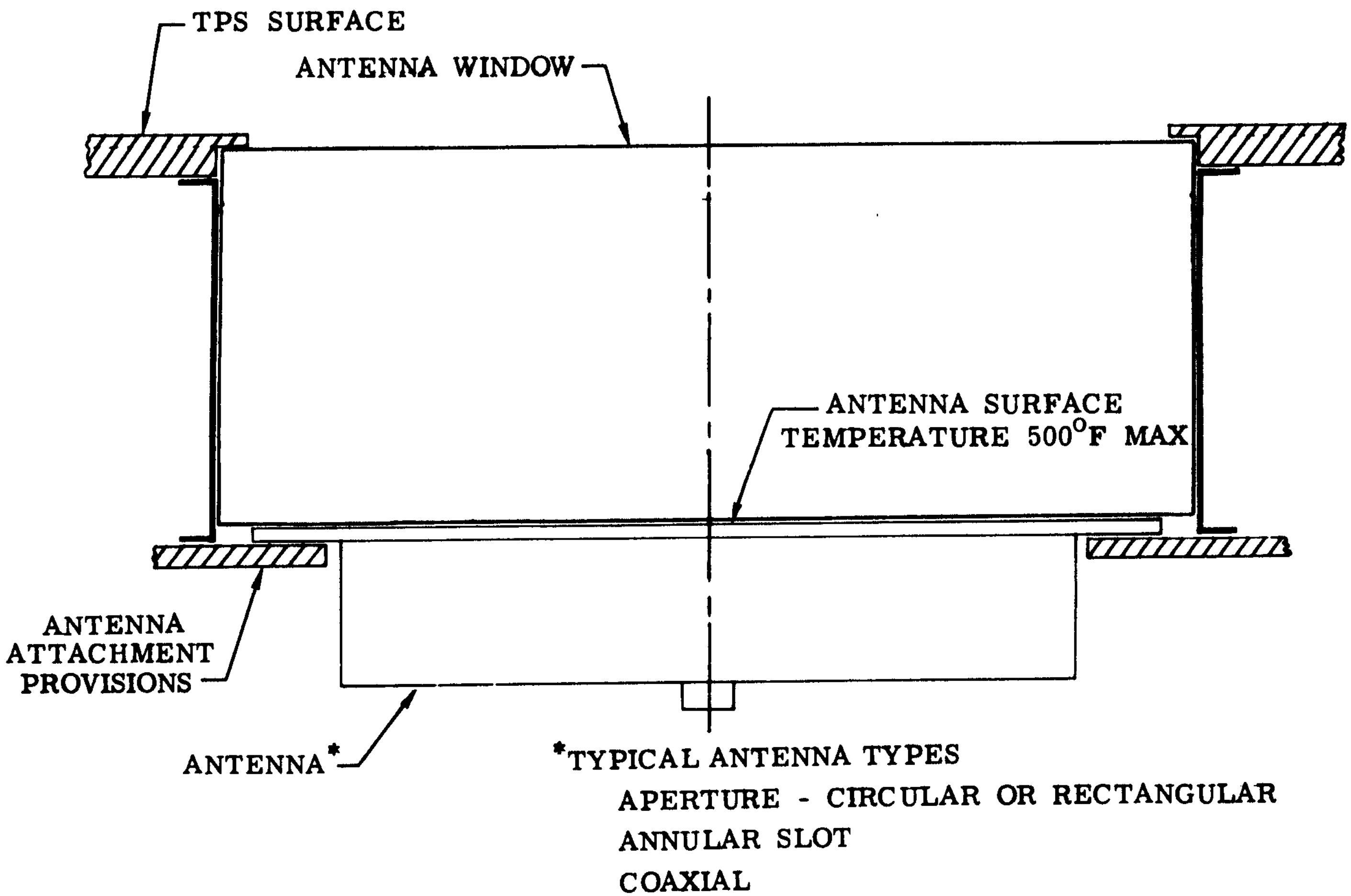
- CHOOSE TYPICAL ANTENNA TYPES THAT MEET SHUTTLE REQUIREMENTS
- DEVELOP ANALYTICAL METHODS FOR COMPUTER,-AIDED DESIGN OF SUCH ANTENNAS
- CHECK DESIGN METHODS BY USE OF SCALE MODELS OF SPACE SHUTTLE SHAPES

ANALYTICAL METHODS

- APERTURE FIELDS OF PROTOTYPE ANTENNAS
- EFFECTS OF EDGES ON ANTENNA PATTERNS
- EFFECTS OF CURVATURE ON ANTENNA PATTERNS
- SCALE MODEL ANTENNA MEASUREMENTS

ANTENNA WINDOW CONFIGURATION

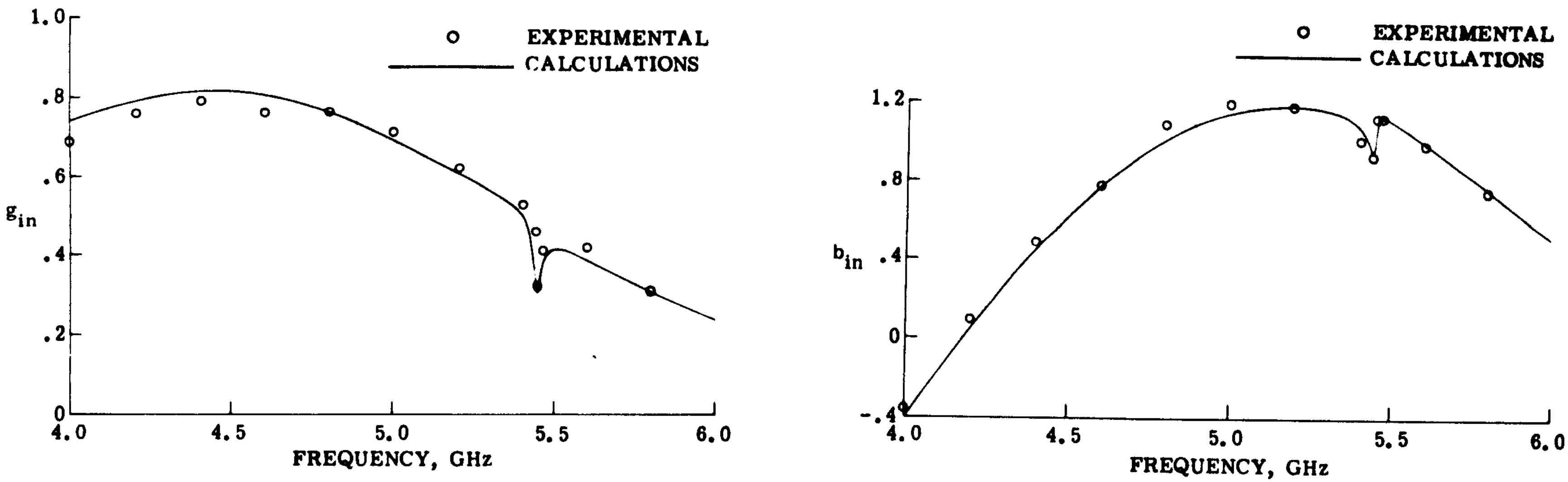
This slide is an outline sketch showing a typical Space Shuttle antenna installation. It is proposed that all antennas for Space Shuttle use be recessed under a dielectric layer or be plugged to reduce the operational reentry temperature of the antenna metallic structure. Such a design is particularly important for extending the reuse capability of operational antenna systems. Several types of antenna configurations have been chosen as typical for meeting Space Shuttle electronic systems requirements. These antenna types are the annular slot, waveguide, or slot fed horn antennas. All of these antennas are being analyzed to determine the aperture fields and admittance as a function of operating frequency, plug thickness and dielectric constant, and the external dielectric insulation or antenna window properties. The aperture fields are then used to determine the radiation pattern of the typical antenna types mounted on Space Shuttle vehicle shapes. Parts of this analytical work have been completed and computer programs have been written and are operating.



ANTENNA/WINDOW CONFIGURATION

ADMITTANCE OF A RECTANGULAR WAVEGUIDE ANTENNA LOADED WITH A QUARTZ DIELECTRIC PLUG

One type of waveguide antenna that has a plug in the aperture has already been analyzed. It has been determined that resonances can occur which are dependent upon the dielectric constant dimensions of the plug and waveguide and the operating frequency. An example of the effect on the input admittance is given in this slide. The resonance is the bump in the corresponding curves of aperture conductance g_{in} and aperture susceptance b_{in}. In other antennas having larger apertures, the resonances produce even larger admittance changes. It is to be noted that if the resonances can be avoided, the plugged antennas can be designed to have good admittance characteristics.



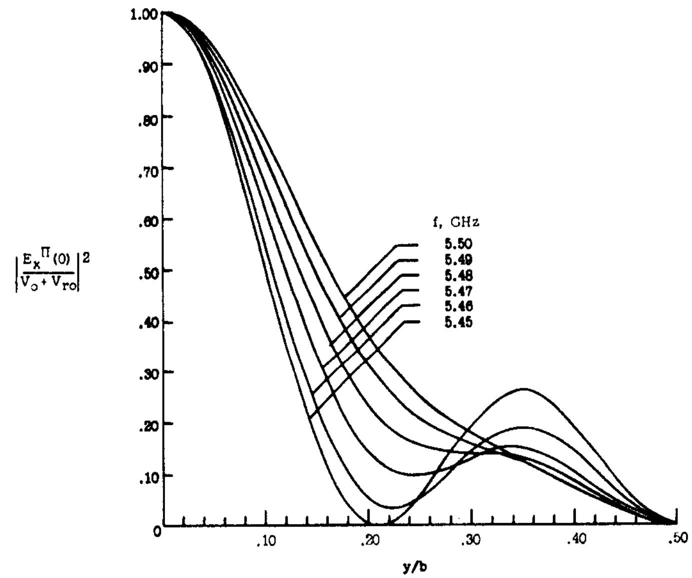
INPUT ADMITTANCE OF A RECTANGULAR WAVEGUIDE

LOADED WITH A QUARTZ PLUG

APERTURE FIELD DISTRIBUTIONS IN THE RESONANCE REGION OF A QUARTZ PLUGGED RECTANGULAR WAVEGUIDE

In the vicinity of the resonance region, shown in the previous slide, there are large changes in the aperture field of the plugged waveguide antenna. These changes, which are shown in this slide as a function of the normalized waveguide half dimension y/b, should be compared to a cosine distribution normally produced in the aperture.

These large changes in the aperture field can produce unexpected nulls in an otherwise smooth antenna pattern. Indeed, such nulls have been observed in the resonance region of a number of different types of plugged reentry antennas.

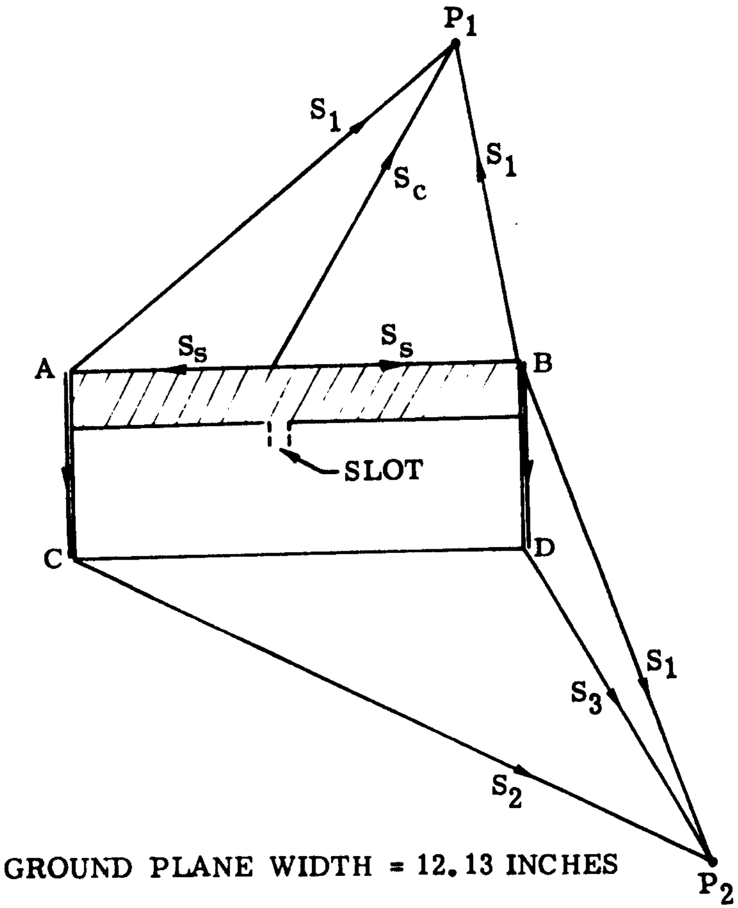


PLOTS OF THE APERTURE ELECTRIC FIELD DISTRIBUTION

DIELECTRIC COATED GROUND PLANE

Knowing the aperture fields of a dielectric plugged or coated antenna mounted on a flat ground plane, it is sometimes possible to predict the pattern of such an antenna when it is mounted on a complex shaped surface. Of particular importance to pattern shape are the effects of edges or sharp corners.

An example of treating such edge problems has been worked out by Ohio State University using a modified form of the geometrical theory of diffraction. Depicted in this slide are the equivalent ray produced fields in the region above the ground plane at P_1 and below the ground plane at P_2. For example, the field observed at P_1 is the sum of the direct slot field S_c and the two surface ray S_s fields diffracted and radiated at points A and B.



GROUND PLANE WIDTH = 12.13 INCHES

GROUND PLANE HEIGHT = 1.71 INCHES

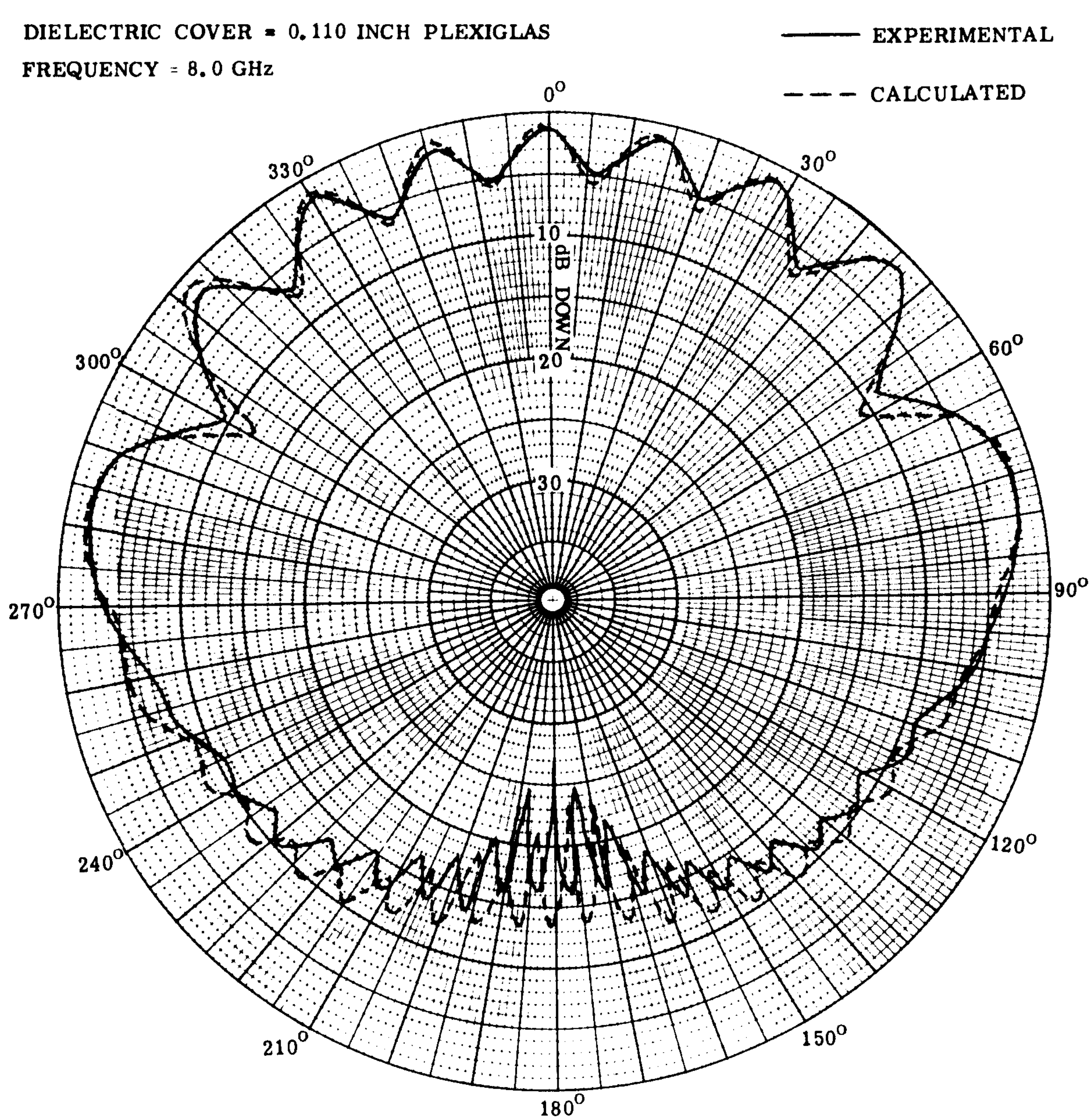
SLOT WIDTH = 0.062 INCH

RAYS EMANATING FROM A SLOT IN A DIELECTRIC CLAD GROUND PLANE.

PATTERN OF A SLOT IN A DIELECTRIC COVERED GROUND PLANE

Using the dimensions given in the previous slide, a ground plane was constructed and a dielectric cover ($\epsilon = 2.57$) placed over it. Patterns for various thickness covers were measured and computed. A typical result is given in this slot where 0° represents the direction directly above the slot in the ground plane. Notice that these results compare favorably. It was found that detailed agreement of a points of the pattern is precluded by tolerances of construction in the experimental models. This is the first time such a theoretical solution has been accomplished.

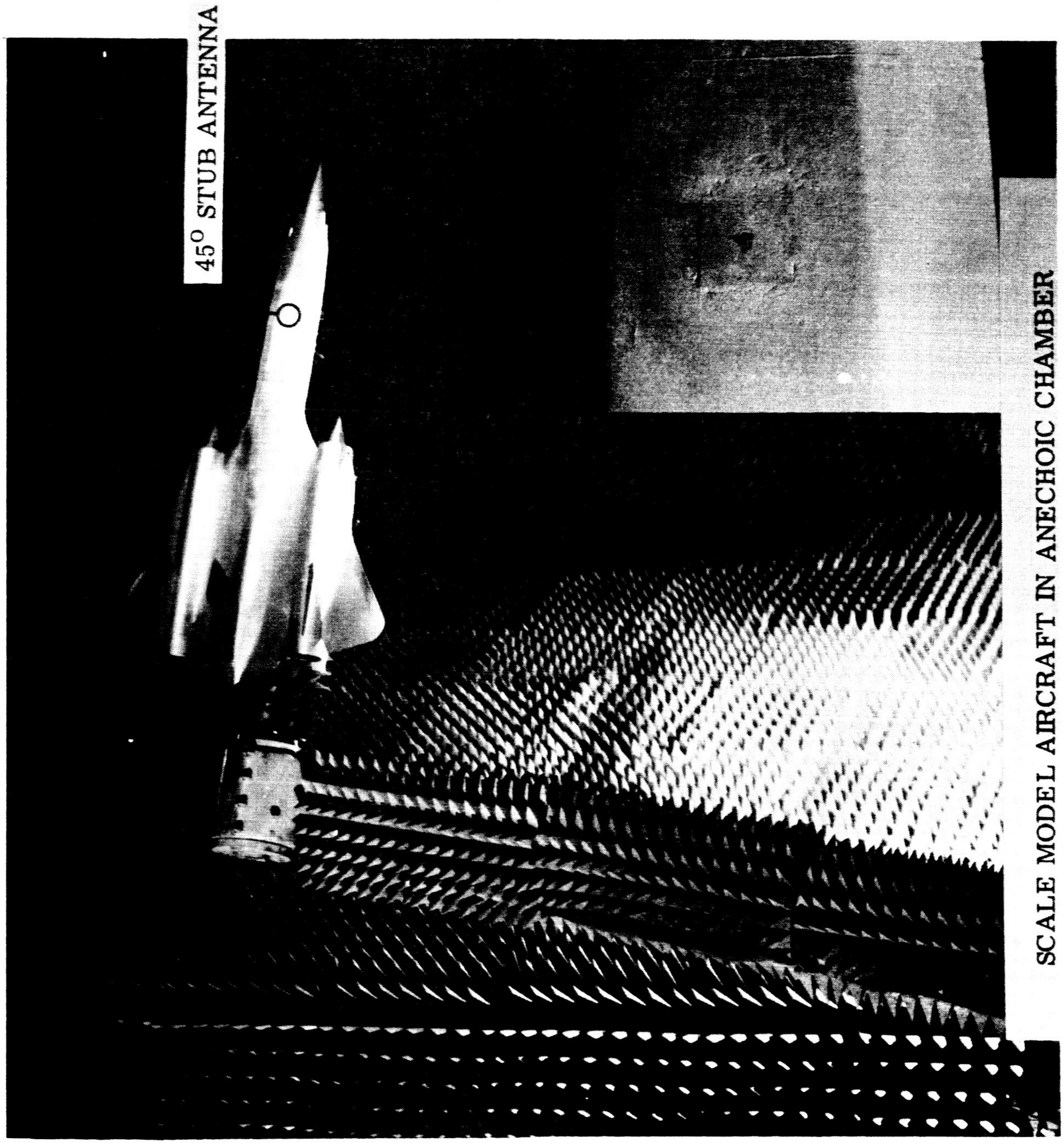
DIELECTRIC COVER = 0.110 INCH PLEXIGLAS
FREQUENCY = 8.0 GHz



PATTERN OF A SLOT IN A DIELECTRIC COVERED GROUND PLANE

1/24th SCALE MODEL AIRCRAFT

This slide shows a photograph of a scale model of an aircraft being used for antenna design studies in the antenna chamber at LRC. This antenna design study is being conducted for FRC at Edwards Air Force Base. The insert shows the scale model antenna at 35 GHz which is being used to determine the effects of the aircraft structure on two antenna excitation modes.



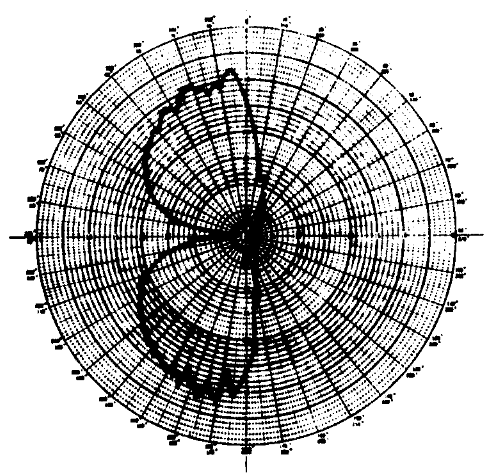
SCALE MODEL AIRCRAFT IN ANECHOIC CHAMBER

RADIATION PATTERNS MEASURED AT 35 GHz USING A ONE TWENTY-FOURTH SCALE MODEL AIRCRAFT

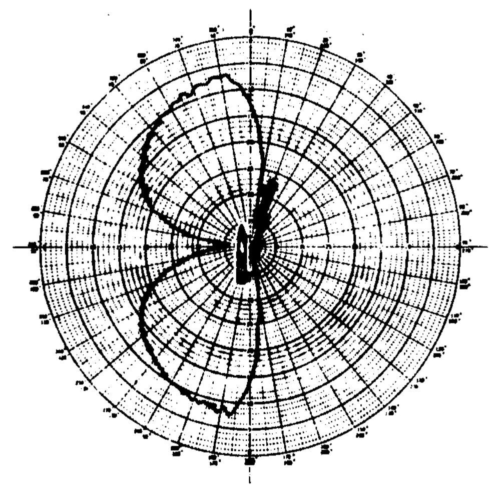
In order to demonstrate some of the problems associated with designing antennas on large spacecraft and the usefulness of scale model measurements, three patterns are presented in a series of slides. All of these patterns are principal plane cuts through the axis of a small stub antenna mounted on the bottom of the 1/24th scale model aircraft shown in the previous slide or in one instance an equivalent flat plate. For example, consider the middle pattern which is one of a short vertical stub on the aircraft. Notice the null directly below the aircraft and the fine ripple structure as we approach the nose or tail region. Now compare this middle pattern with the one on the left of the same small vertical stub mounted at the same point on a flat metal plate the same width and length as the aircraft fuselage. Notice that the overall shape of this pattern is similar to that of the aircraft mounted antenna except for the large ripple structure near the equivalent nose and tail region. This comparison gives an indication of the effects of sharp edges and of the importance of using accurate scale models to obtain detailed patterns.

By bending the stub to a 45 degree angle, one can fill in the pattern underneath the aircraft as shown in the third pattern at the sequence. Consequently, most commercial aircraft use a bent stub or blade antenna on the top and bottom of the airplane for communication purposes. For Space Shuttle applications, such external antennas are not suitable; however, by a combination of the flush mounted types of aperture antennas discussed earlier in this paper, similar patterns can be produced on Space Shuttle shaped vehicles.

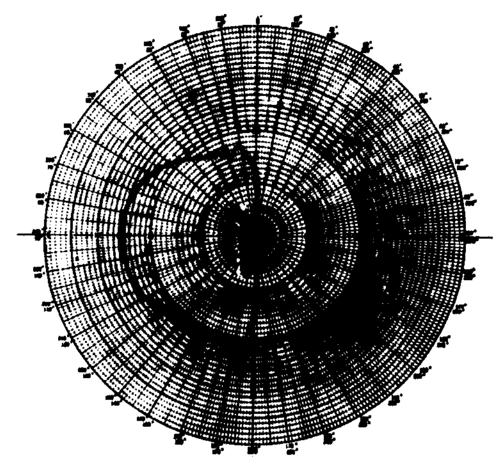
STUB MOUNTED OF FLAT GROUND PLANE



STUB MOUNTED ON THE BOTTOM OF A ONE TWENTY-FOURTH SCALE MODEL AIRCRAFT.



45° STUB MOUNTED ON THE BOTTOM OF A ONE TWENTY-FOURTH SCALE MODEL AIRCRAFT



BLACKOUT CALCULATIONS

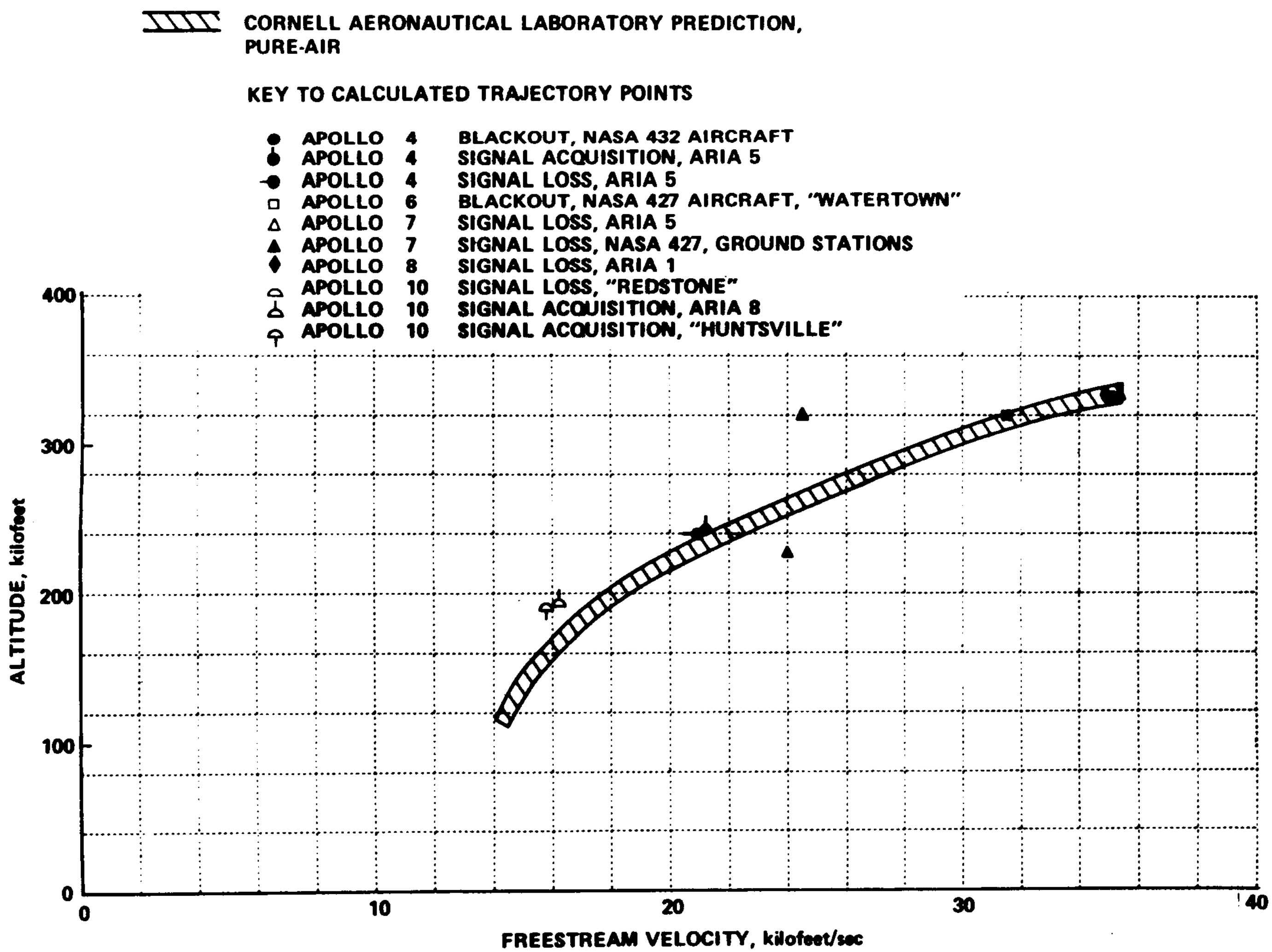
OBJECTIVE: TO DEFINE THE BLACKOUT BOUNDARIES FOR VARIOUS ANTENNA LOCATIONS ON SPACE SHUTTLE VEHICLES

APPROACH:

- DEVELOP ANALYTICAL METHODS WHICH EXTEND APPOLLO DEVELOPED COMPUTER PROGRAMS TO SPACE SHUTTLE CONFIGURATIONS AND CONDITIONS
- CHECK ANALYTICAL METHODS BY PREDICTING MEASURED PLASMA PROPERTIES FOR RAM C VEHICLES
- PERFORM PARAMETRIC CALCULATIONS ON SPACE SHUTTLE SHAPES WITH TYPICAL TRAJECTORIES

COMPARISON BETWEEN PREDICTED AND FLIGHT DATA BLACKOUT BOUNDARIES

This slide presents the available measured blackout conditions for Apollo reentry along with predictions run by Cornell Aeronautical Laboratory. Further discussion of these results is available in NASA SP-252 published in February 1971.



COMPARISON BETWEEN PREDICTED AND FLIGHT DATA BLACKOUT BOUNDARIES