NASA Technical Memorandum 87357

# Near-Field Testing of the 30-GHz TRW Proof-of-Concept Multibeam Antenna

(NASA-TM-87357) NEAR-FIELD TESTING OF THE 30 GHz TRW PRCOF-CF-CCNCEPT MUITIEEAM ANTENNA (NASA) 11 p HC A02/MF A01 CSCL 09C N86-27578

Unclas
G3/33 43238

Richard R. Kunath, Jr. and Robert J. Zakrajsek
*Lewis Research Center*
*Cleveland, Ohio*

Prepared for the
Antenna Measurements Techniques Association Eighth Annual Meeting and Symposium
cosponsored by the National Research Council Canada, David Florida Laboratory, and the AMTA
Ottawa, Canada, September 23–25, 1986

NASA

# NEAR-FIELD TESTING OF THE 30-GHz TRW PROOF-OF-CONCEPT MULTIBEAM ANTENNA

Richard R. Kunath, Jr. and Robert J. Zakrajsek

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

Near-field testing was conducted on the 30 GHz TRW proof-of-concept (POC) Multibeam Antenna (MBA). The TRW POC MBA is a dual offset cassegrain reflector system using a 2.7 m main reflector. This configuration was selected to assess the ability to create both multiple fixed and scanned spot beams. The POC configuration investigated frequency reuse via spatial separation of beams, polarization selectivity and time division multiple access scanning at 30 GHz.

Measurements of directivity, sidelobe level, and pattern were made at NASA Lewis Research Center's Near-Field Antenna Test Facility. Presented in this paper are complete results of these measurements. Included is a detailed discussion of all testing procedures and parameters. Results of additional testing used to evaluate diffraction effects of the subreflector and distortions of the main reflector are also presented.

## INTRODUCTION

As part of its satellite communications program, Lewis has been investigating advanced antenna concepts at Ka-band frequencies that support greater frequency reuse. One concept uses multiple fixed and scanned spot beams to allow for multiple independent users. This paper will discuss the testing of a proof-of-concept (POC) antenna built to demonstrate the feasibility of the mulitple beam concept.

## MULTIPLE BEAM ANTENNA (MBA) CONFIGURATION

The POC MBA is a dual offset reflector, linearly polarized antenna using a 2.67 m diameter parabolic primary reflector and a hyperbolic subreflector (Fig. 1). This antenna was built in support of the Lewis Space Communications POC Technology Program under NASA contract NAS3-22499 (Ref. 1). A polarization selective subreflector is used in conjunction with orthogonally mounted feeds to enhance frequency reuse.

The feed assemblies contain three types of feeds (Fig. 2). Seven circular aperture dual mode horns are used to create three horizontally polarized (Cleveland, Atlanta, and Los Angeles) and four vertically polarized (Tampa, Houston, Chicago, and Denver) fixed spot beams. A cluster of 19 rectangular aperture horns are used in triplet combinations to create 22 scanned spot beams to cover a one-sixth CONUS sector scanned region. A diplexed cluster of 16 circular aperture horns is used to create three contoured spot beams for Boston/New York/Washington D.C. coverage. This paper will discuss only the fixed spot and scanned spot beam feed testing results.

The fixed spot beam feed assemblies were designed to produce a -18 dB illumination taper to yield a 0.3° beamwidth with sidelobes less than -25 dB between 28.5 to 29.0 GHz. To achieve the low sidelobe levels, the primary reflector surface tolerance was to be 2 mils rms.

## TEST PLAN

Characterization of the POC MBA performance was accomplished at the Lewis Antenna Test Facility (ATF). A test plan was written to outline which feed configurations would be tested and at what frequencies. A complete list of all the tested configurations is given in Ref. 2. The tested feeds represent those beams which are used for alignment purposes, which are aimed far from boresight or which aid in evaluating minimum crossover boundaries of beams in the scanned array.

The bandwidth of the antenna system is 27.5 to 30.0 GHz. The fixed spot beam horns were tested at 28.75 GHz, while the scanned spot beam horns were tested at 29.25 GHz. These frequencies represent the mid-band frequency for each feed element. Also, pattern change as a function of frequency was tested for three frequencies (29.00, 29.25, and 29.50 GHz) for a single scanned spot beam triplet.

## MBA ASSEMBLY AND ALIGNMENT

After the POC MBA was tested at the contractor's site, it was disassembled, packaged, and shipped to Lewis. The antenna was broken into three parts: the antenna platform, the primary reflector with its supporting truss, and the feed assemblies and subreflector. The antenna was then reassembled at Lewis on the near-field range.

After reassembly, mechanical alignment measurements were made. Tooling balls had been attached to the platform, primary reflector, subreflector, and to the boresite mounting fixture by the manufacturer previous to shipment. Tooling dimensions from platform to subreflector, platform to primary reflector, and primary reflector to subreflector were measured and checked against preshipment measurements. After careful assembly and adjustment, all of the tooling ball readings were determined to be consistant with the previous values.

The prime focus feed phase pattern was used to electrically align the antenna perpendicular to the near-field plane. The horizontal and vertical feed assemblies were installed on the platform after boresite alignment. No alignment checks were necessary as the feed assembly mounting fixtures were pinned and bolted in place on the antenna platform.

DATA PROCESSING AND RESULTS

Two types of data processing are available for analyzing antenna data sets at the ATF. Subsets of the complete data set can be processed by the ATF Perkin-Elmer 8/32 minicomputer. Complete data sets, due to the large number of points, are processed by the IBM 370 mainframe in the Lewis Research Analysis Center (RAC).

CENTERLINE DIAGNOSTICS

For diagnostic purposes during antenna alignment, a single line of data (usually a centerline) is processed. The output of this processing is a set of three plots: near-field phase, near-field amplitude, and far-field relative power (Figs. 3 to 5). From the near-field phase, antenna pointing and feed focus can be determined. From near-field amplitude, aperture illumination can be determined. From far-field relative power, antenna pointing can be cross checked and major antenna distortions can be seen by their effects on the sidelobe structure.

Near-field phase and amplitude measurements are valuable diagnostic tools. For an ideal antenna (i.e., perfectly focused, symmetric aperture illumination, perfect feed position, and negligible surface distortion) a prime focus feed would produce a flat phase distribution over the aperature and a symmetric (typically $\cos^2$) aperture illumination. As can be seen from Fig. 3, the phase distribution is an uneven concave curve over the aperture. This suggested an unfocused feed as well as a poor surface tolerance. Surface measurements showed that the surface tolerance was only 5.5 mils rms with a 35 mil peak-to-peak deviation. Figure 4 shows a symmetric aperture illumination with an edge taper of approximately -20 dB. This coincides with the low sidelobe level desired. The far-field centerline pattern gives an accurate representation of the mainlobe, first one or two sidelobes, and the overall sidelobe envelope. However, the sidelobe magnitude is generally a few dB higher for a centerline produced far-field due to the limited amount of data processed.

The complete NxN set of near-field data is collected using the automated near-field range. A complete description of both the rf and mechanical capabilities and performance of the near-field range can be found in Ref. 3. A typical data set for this antenna system was 200x200 points spaced at $2\lambda$ centers. Data collection times for these scans were approximately 3 hr/polarization. The probe used was a 15 dB calibrated horn. From previous sample spacing and probe tests (Ref. 4), it was shown that the resultant far-field calculated would be insensitive to probe effects over the angles of interest ($\pm 8^\circ$) and therefore probe corrections were unnecessary.

NxN DATA SET RESULTS

Processing of the complete near-field data set is accomplished remotely at the RAC. A magnetic tape of the near-field data is made at the ATF and is sent to the RAC. Execution of the processing program is performed remotely in the ATF via an interactive graphics terminal. The output of the complete near-field data set processing is a set of near-field and far-field plots.

Two types of plots are available after processing. Contour plots of the near-field phase an amplitude, as well as far-field relative power are options. Also, cuts through the far-field data set in both principle axes and from highest sidelobe peak to mainbeam peak are options.

Figures 6 and 7 are examples of the far-field relative power contours calculated for both the copolarized and crosspolarized data sets of the Tampa fixed spot beam. Highlighted are the -3 dB and -20 dB contours. From the -3 dB contour, a beamwidth of $0.3^\circ$ is evident, while the -20 dB contour bounds the highest sidelobe. The magnitude of this sidelobe is approximately -17 dB. These results are comparable to the results for all of the beams tested. All results were consistent with near-field results obtained by the contractor in terms of beamwidth, sidelobe structure, and gain.

Relative pointing between beams was calculated and measured. Pointing azimuth and elevation angles for all of the fixed spot beams tested were calculated from known latitude and longitude coordinates of the corresponding cities. Before the selected fixed spot beams were tested, the antenna was positioned with the Houston beam perpendicular to the scan plane so it could be used as an alignment reference to determine the relative beam pointings. Before each beam was tested, the alignment of the Houston beam was rechecked and corrected if necessary. Calculated and measured relative beam pointing angles were determined. Using this technique, it was determined that the Houston beam was mispointed by approximately $-0.4^\circ$ in elevation.

ADDITIONAL TESTING

Upon completion of the initial test plan, Lewis took advantage of the opportunity to conduct investigations beyond the scope of the test plan. A brief discussion of this work follows.

Special testing was conducted to improve focusing, measure reflector surface distortions, and predict diffraction effects of the subreflector. To improve focusing, the prime focus feed assembly position was varied towards and away from the reflector with respect to its original position. The best overall focussing was obtained by moving the feed assembly 3.2 in. toward the reflector from its original position.

Photogrammetry measurements were made to evaluate the reflector surface accuracy. A set of 621 targets were applied to the primary reflector. By a triangulation of target position from multiple photographs, the target positions were found to the nearest mil. The best fit parabola surface error calculated from this measurement was 8 mils rms. An rf analysis of this surface showed sidelobes around -15 dB, consistent with the previously measured sidelobe performance.

Additional testing was conducted to verify theoretical diffraction predictions. Figure 8 shows the predicted and measured response for microwave radiation diffracted off the MBA POC subreflector. A feed horn was mounted so that its radiated field would impinge on the subreflector edge. A wall of absorber was positioned in front of the primary reflector so that only the spillover and diffracted radiation would be measured on the near-field plane. A complete discussion of this testing can be found in Ref. 4.

## CONCLUSIONS

Near-field testing of the POC MBA was conducted. Testing revealed that large, high gain antennas can be measured with high accuracy. In addition to producing detailed far-field patterns, the near-field approach provides significant diagnostic capabilities. The alignment of the antenna using the near-field phase pattern is far superior to any current mechanical alignment technique. The advantage of using near-field data to determine focusing, beam pointing, and aperture illumination is extremely useful for accurately characterizing advanced complex antenna performance.

## REFERENCES

1. Wong, W.C.; Chen, C.C.; and Duncan, J.W.: 30/20 GHz Multiple Beam Antenna for Space Communications Satellites. NASA CR-174643, 1984.

2. Reinhart, R.: Test Plan for the TRW Multibeam Antenna. NASA Lewis Research Center, Internal Report, July 1984.

3. Sharp, G.R., et al.: Characteristics and Capacities of the NASA Lewis Research Center High Precision 6.7-by 6.7-m Planar Near-Field Scanner. NASA TM-83785, 1984.

4. Acosta, R.J.; and Lee, R.Q.: Case Study of Sample Spacing in Planar Near-Field Measurement of High Gain Antennas. NASA TM-86872, 1984.

5. Lee, S.W., et al.: Near-Field Spillover from a Subreflector: Theory and Experiment. University of Illinois, Electromagnetics Lab Report No. UILU-ENG-86-2547, May 1986.

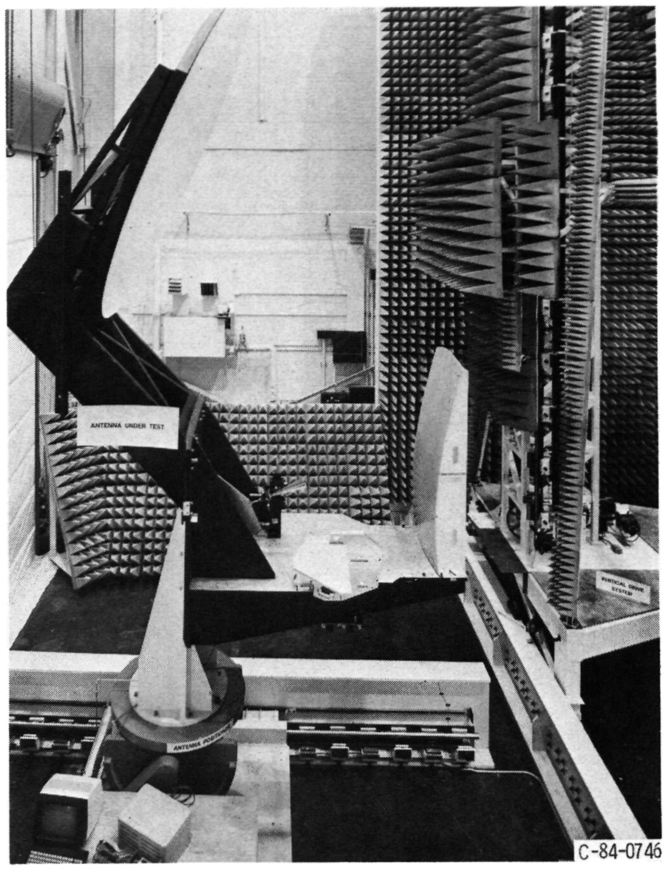



Figure 1. - 30 GHz POC MBA in the NASA-Lewis ATF.

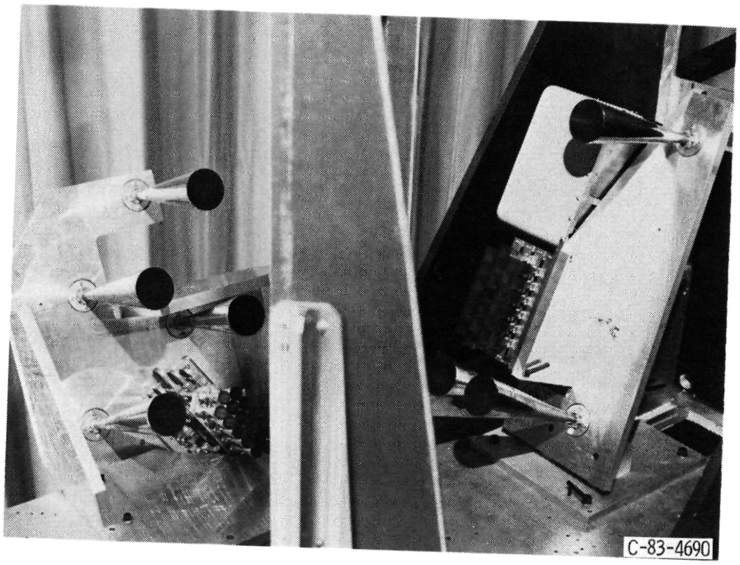



Figure 2. - Feed assemblies for the 30 GHz POC MBA.

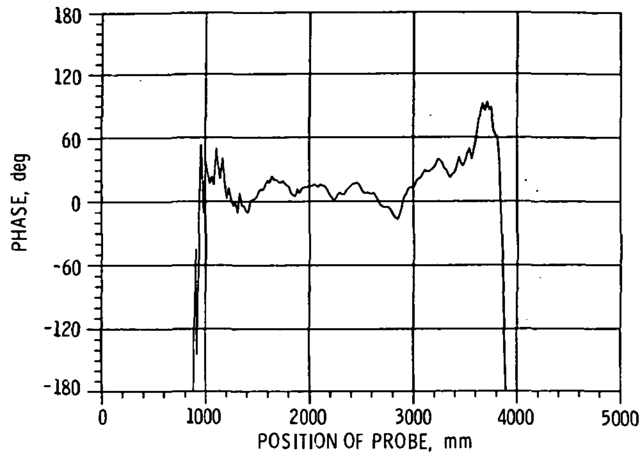



Figure 3. - Centerline near-field phase for the prime focus feed.

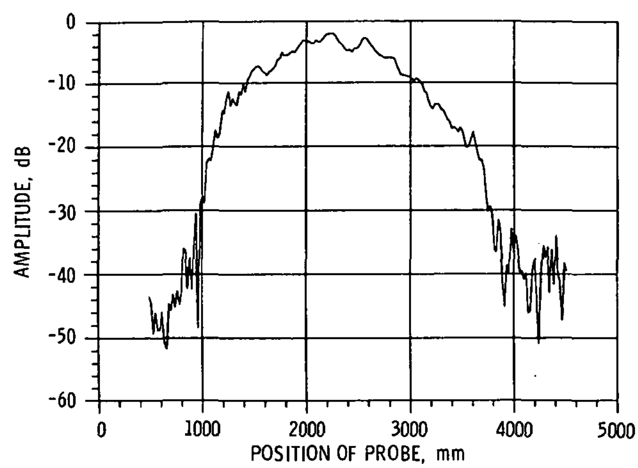



Figure 4. - Centerline near-field amplitude for the prime focus feed.

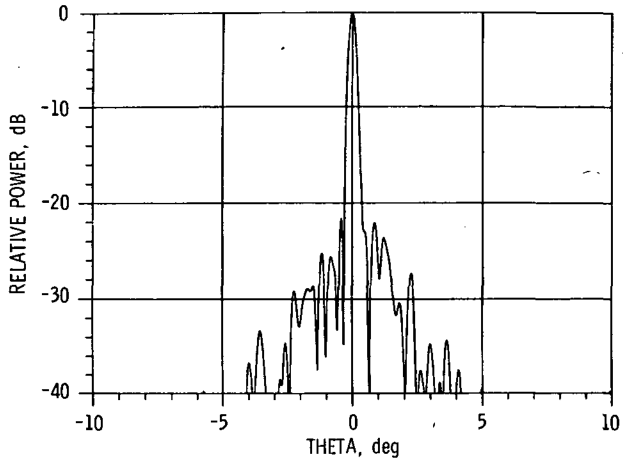
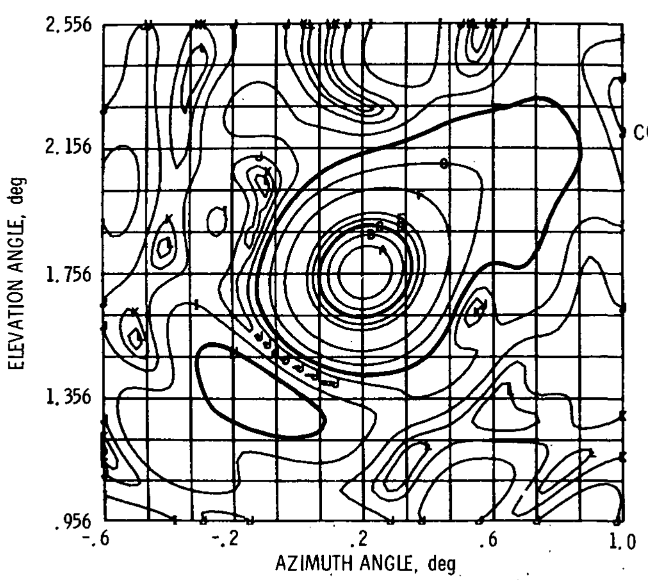



Figure 5. - Far-field relative power from centerline near-field phase and amplitude for the prime focus feed.




| CONTOUR LABEL | CONTOUR VALUE |
|---|---|
| A | -1.000 |
| B | -2.000 |
| C | -3.000 |
| D | -4.000 |
| E | -5.000 |
| F | -10.000 |
| G | -15.000 |
| H | -20.000 |
| I | -25.000 |
| J | -30.000 |
| K | -35.000 |
| L | -40.000 |

Figure 6. - Far-field copolarized relative power contours for the Tampa fixed spot beam.

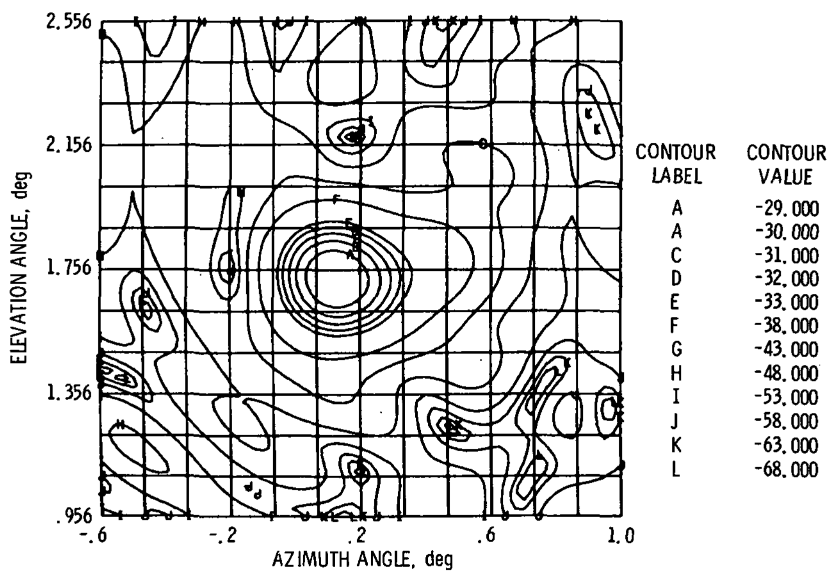



Figure 7. - Far-field crosspolarized relative power contours for the Tampa fixed spot beam.

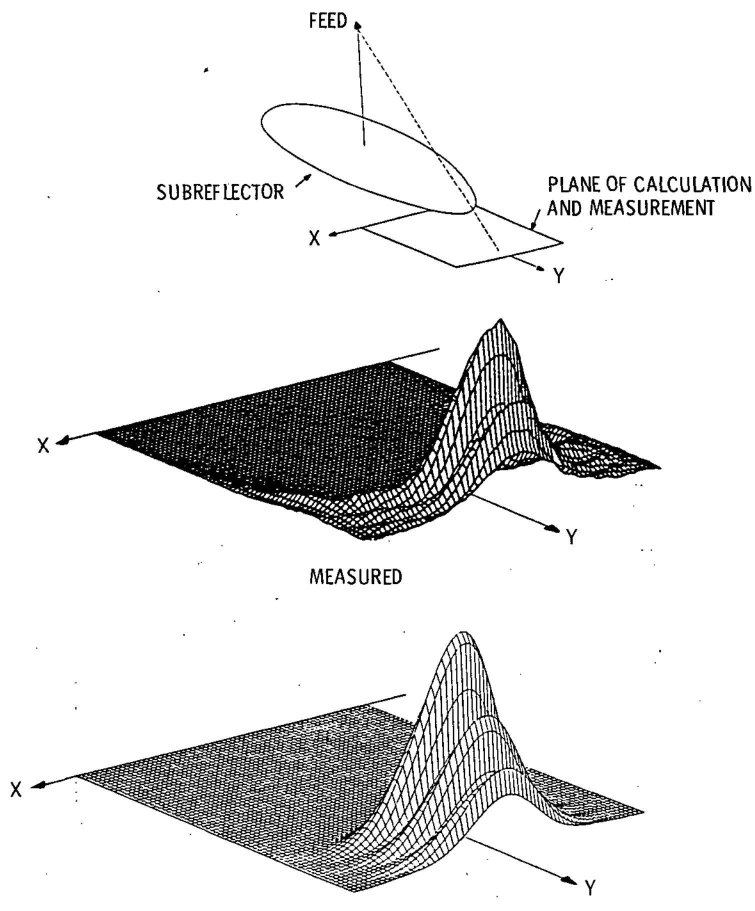


Figure 8. - Near-field diffraction pattern of the POC MBA subreflector.

| | | |
|---|---|---|
| 1. Report No.<br>NASA TM-87357 | 2. Government Accession No. | 3. Recipient's Catalog No. |

| | |
|---|---|
| 4. Title and Subtitle<br>Near-Field Testing of the 30 GHz TRW Proof-of-Concept Multibeam Antenna | 5. Report Date<br><br>6. Performing Organization Code<br>505-41-21 |
| 7. Author(s)<br>Richard R. Kunath, Jr. and Robert J. Zakrajsek<br>ND315157 | 8. Performing Organization Report No.<br>E-3115<br><br>10. Work Unit No. |
| 9. Performing Organization Name and Address<br>National Aeronautics and Space Administration<br>Lewis Research Center<br>Cleveland, Ohio 44135 | 11. Contract or Grant No.<br><br>13. Type of Report and Period Covered<br>Technical Memorandum |
| 12. Sponsoring Agency Name and Address<br>National Aeronautics and Space Administration<br>Washington, D.C. 20546 | 14. Sponsoring Agency Code |

15. Supplementary Notes

Prepared for the Antenna Measurements Techniques Association Eighth Annual Meeting and Symposium cosponsored by the National Research Council Canada, David Florida Laboratory, and the AMTA, Ottawa, Canada, September 23-25, 1986.

16. Abstract

Near-field testing was conducted on the 30 GHz TRW proof-of-concept (POC) Multibeam Antenna (MBA). The TRW POC MBA is a dual offset cassegrain reflector system using a 2.7 m main reflector. This configuration was selected to assess the ability to create both multiple fixed and scanned spot beams. The POC configuration investigated frequency reuse via spatial separation of beams, polarization selectivity and time division multiple access scanning at 30 GHz. Measurements of directivity, sidelobe level, and pattern were made at NASA Lewis Research Center's Near-Field Antenna Test Facility. Presented in this paper are complete results of these measurements. Included is a detailed discussion of all testing procedures and parameters. Results of additional testing used to evaluate diffraction effects of the subreflector and distortions of the main reflector are also presented.

| | |
|---|---|
| 17. Key Words (Suggested by Author(s))<br>30 GHz Multibeam antenna testing | 18. Distribution Statement<br>Unclassified - unlimited<br>STAR Category 33 |

| | | | |
|---|---|---|---|
| 19. Security Classif. (of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of pages | 22. Price* |

*For sale by the National Technical Information Service, Springfield, Virginia 22161

National Aeronautics and
Space Administration

**Lewis Research Center**
Cleveland, Ohio 44135

**Official Business**
**Penalty for Private Use $300**

SECOND CLASS MAIL

ADDRESS CORRECTION REQUESTED

Postage and Fees Paid
National Aeronautics and
Space Administration
NASA-451

NASA