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A Portable Ku-Band Front-End Test Package for Beam-Waveguide Antenna Performance Evaluation

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This article presents the design of a Ku-band test package for the new beam-waveguide (BWG) antenna at 11.7–12.2 GHz. Results of linear polarization measurements with the test package on the ground are also presented. This report is the fifth in a series of articles concerned with test-package design and performance.

I. Introduction

A new 34-m beam-waveguide (BWG) antenna has been built at Deep Space Station 13 (DSS 13) in the Goldstone Deep Space Communications Complex near Barstow, California. This antenna is designed to be efficient at X-, Ku-, and Ka-bands, and it is the first NASA tracking antenna to use a BWG design. The antenna's focal points for the center-pass mode are shown in Fig. 1.

The unique methodology used to test the new BWG antenna included making measurements at the Cassegrain focal point and then at the final focal point in the pedestal room. Measurements made at the Cassegrain focal point F1 give information concerning panel settings, subreflector defocus, and far-field antenna patterns. Measurements made at the pedestal room focal point F3 provide amplitude and phase information on the entire BWG system, which includes the main reflector, subreflector, and six BWG mirrors. Degradations caused by the BWG mirror systems are determined by comparing the measured parameters at the two focal points. Previous articles [1–4] describe the successful employment of X- and Ka-band test packages for the new DSS 13 BWG antenna at 8.45 and 32 GHz.

This is the fifth article in a series of reports on the design and performance of X-, Ka-, and Ku-band test packages that were developed specifically for testing the BWG antenna. The Ku-band test package is used primarily for making holographic measurements [5]. In this article, only a description of the Ku-band test package and results from a linear polarization test will be given. In another report, it was shown that the Ku-band test package was used successfully at the BWG antenna Cassegrain focal point F1 to obtain holographic panel-setting information.[1] The Ku-band test package will be employed in the near future for making holographic measurements at F3 and also for making BWG frequency-stability measurements, as described in a companion article [6].

[1] B. L. Seidel and D. J. Rochblatt, Chapter 4, *DSS-13 Beam-Waveguide Antenna Project, Phase 1 Final Report,* JPL D-8451 (internal document), Jet Propulsion Laboratory, Pasadena, California, May 15, 1991.

II. Ku-Band Test-Package Design

Figure 2 shows the system block diagram of the Ku-band test package. Depicted are such Cassegrain front-end microwave components as the horn, cosine taper, circular waveguide rotary joint, the circular waveguide to waveguide-rectangular (WR) 75 transition, and the low-noise amplifier (LNA). The microwave system is designed to operate over a Ku-band frequency range of 11.7–12.2 GHz. For holographic measurements, an Eikontech Holographic Receiver system was used to downconvert the Ku-band frequency to an intermediate frequency (IF) of approximately 482 MHz.

The 22-dBi horn assembly has an aperture diameter of 5.004 in. and tapers linearly over a length of 18.414 in. to a diameter of 0.968 in. A 4-in.-long cosine taper provides a gradual transition from the horn output diameter of 0.968 in. to the circular rotary joint diameter of 0.879 in. The Ku-band circular waveguide rotary joint is a scale model of the DSN version used in the X-band test package [1] and other Cassegrain cone assemblies. To enable linear polarization to be varied to the desired rotation angle, the LNA is supported by a pair of orthogonal brackets with an axle-hole design that permits the amplifier (and follow-up coaxial cable) to be manually rotated 360 deg. A clamp is used to prevent further rotation of the assembly once the optimum linear polarization-output orientation is found for the incoming signal.

Testing the antenna at F1 and F3 required the test package to be convertible from 29- to 22-dBi horn configurations. The conversion is accomplished by using horn extensions of the same linear taper going from an aperture diameter of ~13.46 to 5.004 in., over a length of 38.58 in. Figure 3 shows the Ku-band test package in the 29-dBi horn configuration installed at the Cassegrain focal point F1. Figure 4 shows the test package in the 22-dBi horn configuration ready for installation on the mounting table at focal point F3. The height of the 29-dBi horn configuration, as measured from the horn aperture to the base of the frame assembly, is about 11 ft, while the height of the 22-dBi horn test-package configuration is about 39 in. shorter.

III. Test Results

Figure 5 is a photograph of the Ku-band test package undergoing linear polarization tests at JPL. A block diagram of the test setup appears in Fig. 6. The transmit horn was pyramidal (Scientific-Atlanta model 12-7.0), with aperture dimensions of 5.04 × 3.73 in. and WR 112 at its input. The separation distance of 44.2 in. corresponded to 1.72 D^2/λ, where λ is the free-space wavelength for the test frequency of 11.95 GHz, and D corresponds to the 5.04-in. dimension of the pyramidal horn. Linear polarization tests were performed by rotating the lower half of the test-package circular rotary joint and measuring received signal levels with the equipment shown in Fig. 6.

The results of the polarization tests are given in Fig. 7. Good agreement was obtained between theoretical and experimental data. The measured depths of the nulls were ~−47 dB down from the peak when the two horns were cross-polarized with respect to each other. The test results verified that the Ku-band test-package system would receive linearly polarized signals at desired rotation angles and reject cross-polarized signals.

The Y-factor noise-temperature measurements made with aperture-ambient and liquid-nitrogen loads showed that the Ku-band operating noise temperature was 172 K, as defined at the Ku-band horn aperture. Most of this operating noise temperature was due to the 160 K LNA in the system (see Fig. 2).

IV. Concluding Remarks

The Ku-band test package was tested in an on-the-ground configuration and was found to perform according to the design goals. Other reports showed that the test package was stable and performed well when used at the BWG Cassegrain focal point F1 for holographic measurements at 46.5- , 37.0- , and 12.7-deg. elevation angles.[2]

[2] Ibid.

Acknowledgment

The authors gratefully acknowledge H. Reilly who provided the Ku-band rotary joint for the test package.

References

[1] T. Y. Otoshi, S. R. Stewart, and M. M. Franco, "A Portable X-Band Front-End Test Package for Beam-Waveguide Antenna Performance Evaluation—Part I: Design and Ground Tests," *TDA Progress Report 42-103*, vol. July–September 1990, Jet Propulsion Laboratory, Pasadena, California, pp. 135–150, November 15, 1990.

[2] T. Y. Otoshi, S. R. Stewart, and M. M. Franco, "A Portable X-Band Front-End Test Package for Beam-Waveguide Antenna Performance Evaluation—Part II: Tests on the Antenna," *TDA Progress Report 42-105*, vol. January–March 1991, Jet Propulsion Laboratory, Pasadena, California, pp. 54–68, May 15, 1991.

[3] T. Y. Otoshi, S. R. Stewart, and M. M. Franco, "A Portable Ka-Band Front-End Test Package for Beam-Waveguide Antenna Performance Evaluation—Part I: Design and Ground Tests," *TDA Progress Report 42-106*, vol. April–June 1991, Jet Propulsion Laboratory, Pasadena, California, pp. 249–265, August 15, 1991.

[4] T. Y. Otoshi, S. R. Stewart, and M. M. Franco, "A Portable Ka-Band Front-End Test Package for Beam-Waveguide Antenna Performance Evaluation—Part II: Tests on the Antenna," *TDA Progress Report 42-106*, vol. April–June 1991, Jet Propulsion Laboratory, Pasadena, California, pp. 266–282, August 15, 1991.

[5] D. J. Rochblatt and Y. Rahmat-Sammi, "Effects of Measurement Errors on Microwave Antenna Holography," *IEEE Transactions on Antennas and Propagation*, vol. 39, no. 7, pp. 933–942, July 1991.

[6] T. Y. Otoshi, "A Proposed Far-field Method for Frequency Stability Measurements on the DSS 13 Beam-Waveguide Antenna," *TDA Progress Report 42-107*, vol. July–September 1991, Jet Propulsion Laboratory, Pasadena, California, pp. 81–87, November 15, 1991.

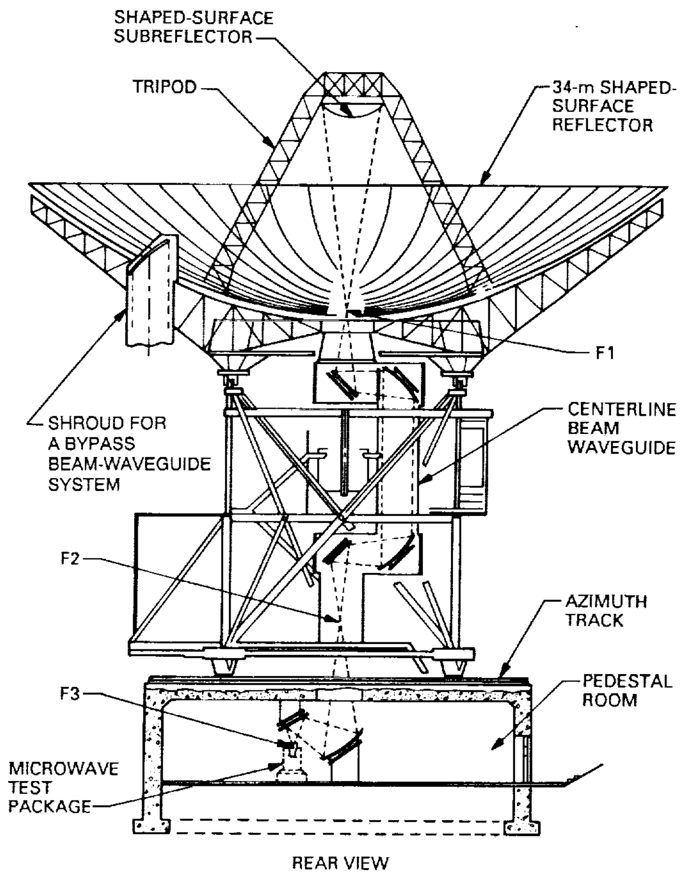

Fig. 1. The BWG antenna in the center-pass mode, showing focal points F1, F2, and F3 for testing with the portable test package.

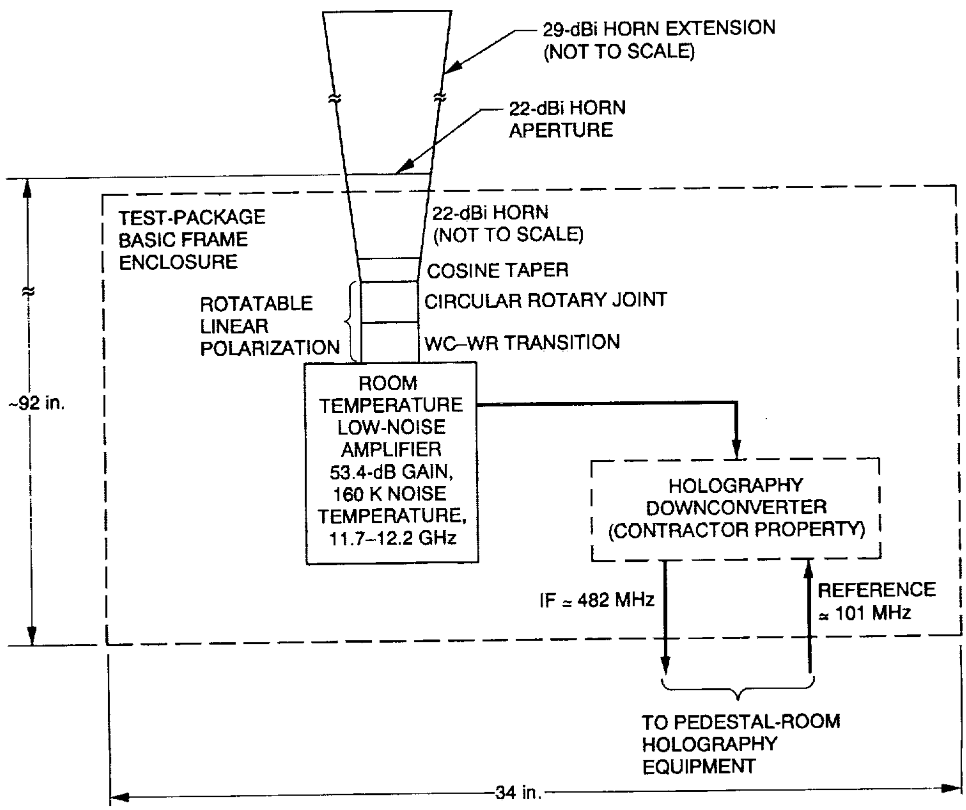

Fig. 2. A block diagram of the Ku-band test-package system.

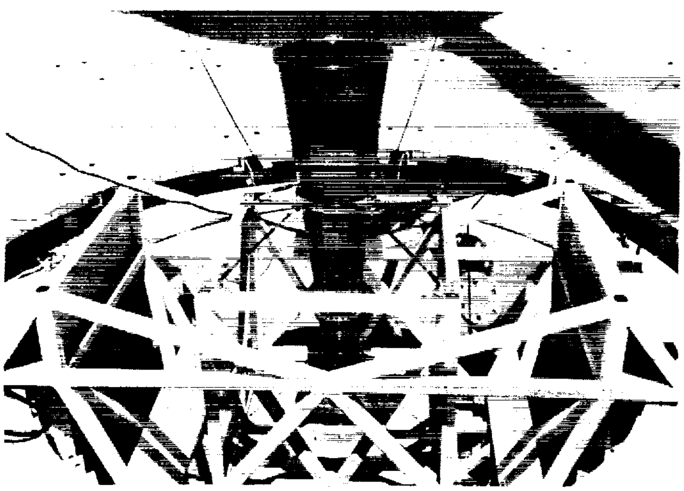

Fig. 3. The Ku-band test package mounted at F1 in the 29-dBi horn configuration.

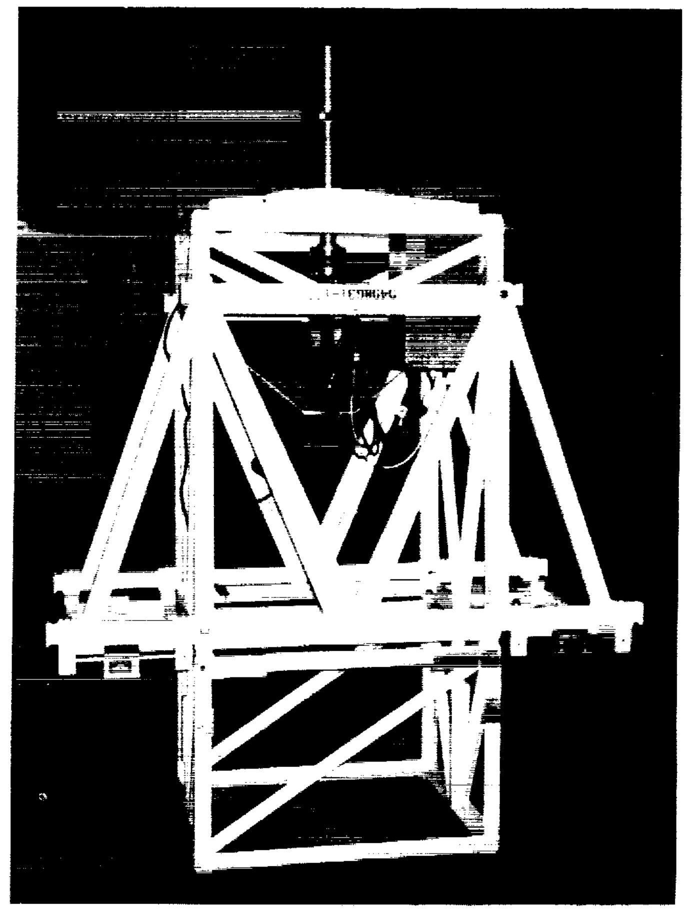

Fig. 4. The Ku-band test package assembly in the 22-dBi horn configuration prior to installation on the mounting table at F3.

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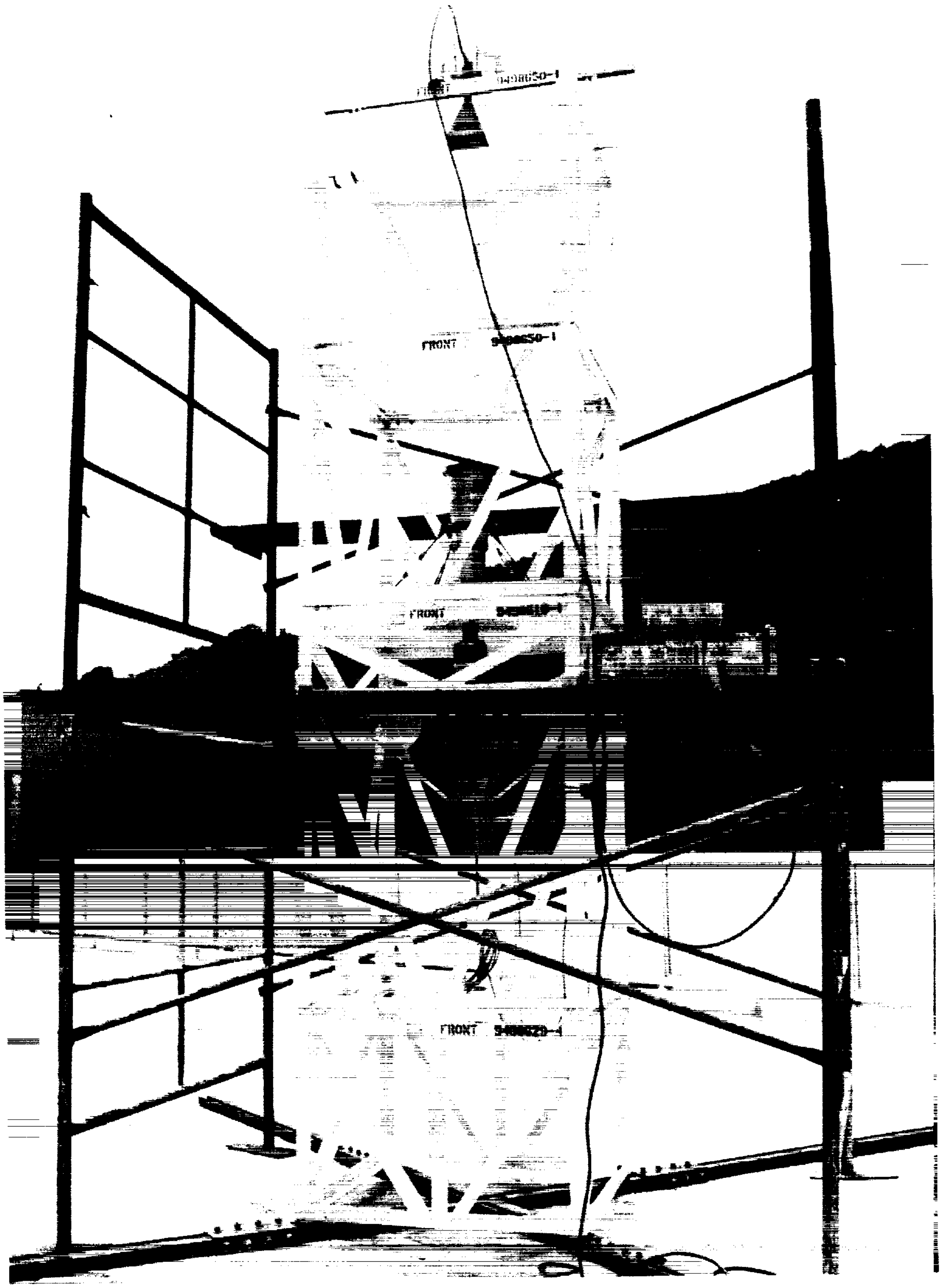

Fig. 5. The test setup for linear polarization tests on the Ku-band test package at JPL.

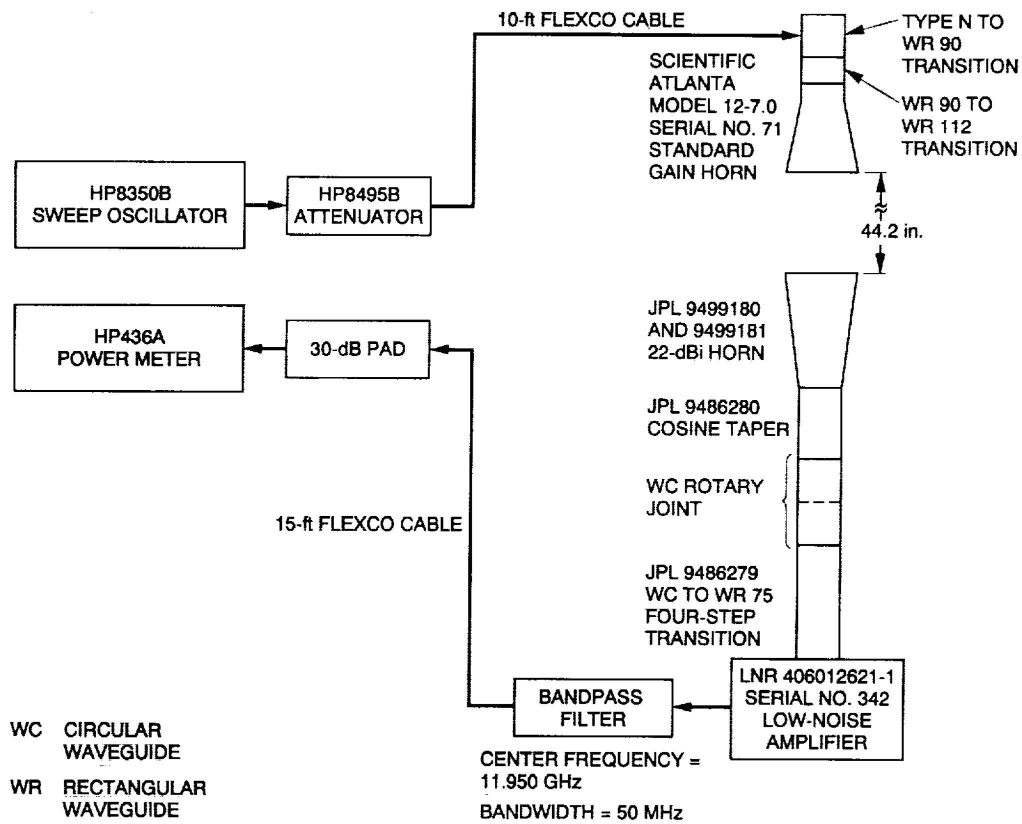

Fig. 6. A block diagram of the linear polarization test setup at 11.950 GHz.

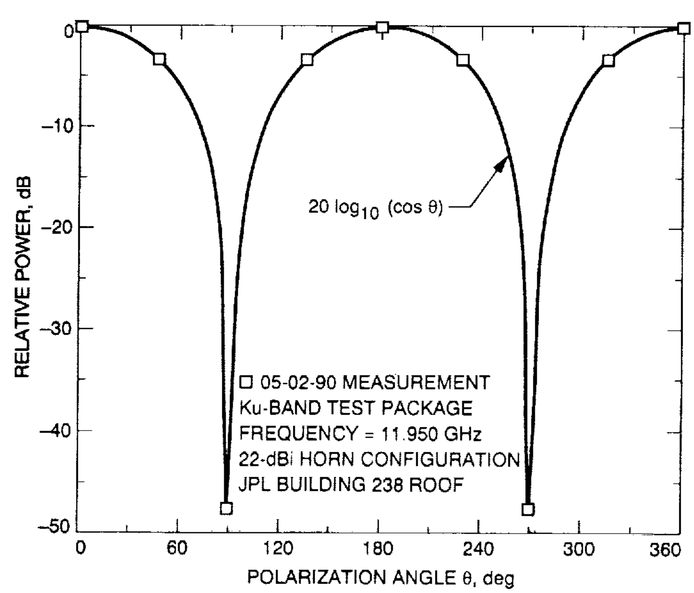

Fig. 7. Theoretical and experimental polarization loss versus polarization angle.