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DESIGN AND CALIBRATION OF MICROWAVE ANTENNA GAIN STANDARDS

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ABSTRACT

A set of antenna gain-standard horns covering the microwave range from 0.77 cm to 31.5 cm has been designed and carefully calibrated. The horn fabrication is simple and can be duplicated accurately from the drawings supplied. A simple method of extending and improving the accuracy of Schelkunoff's gain curves is also described.

PROBLEM STATUS

This is a final report on this phase of the problem; work on the problem is continuing.

AUTHORIZATION

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INTRODUCTION

The need for accurate and practical microwave antenna gain standards has led to the design and calibration of a series of pyramidal horns covering the microwave bands from 0.77 cm to 31.5 cm. The series consists of eleven broadband horns having gains ranging from 24.7 db to 13.7 db. There is a horn for each waveguide size in the range. The horns can be easily and accurately duplicated from drawings supplied in this report.

DESIGN

Three requirements were considered of prime importance in the design: a useful gain figure, simplicity of construction, and accuracy of calibration. The fabricated type of horn (Fig. 1), with flat metal sheets forming the sides, was decided upon as the best means of satisfying the construction requirements. For simplicity, the horns were designed so that the E- and H-plane flares meet the waveguide in a common plane.

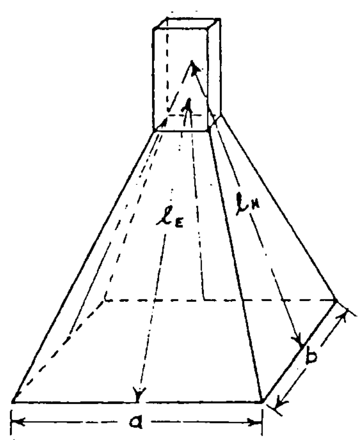

Fig. 1 - Physical dimensions for calculating the gain

Another consideration was the over-all size and weight. It was impractical to scale the horns from one band to another throughout the range, since the horns at the longer wavelengths would be too large and those at the shorter wavelengths too small. Accordingly, there are five different designs; each of the other six horns was scaled from one of these.

The 8-mm and 1.8-cm horns were scaled from the 1.25-cm horn; the 4.75-cm horn from the 3.2-cm horn; the 3.95-cm and 6-cm horns from the 10-cm horn; and the 15-cm horn from the 23-cm horn. In scaling, the values of ℓ_H had to be altered slightly in order to make a simple junction at the waveguide. This was necessary because, with one or two exceptions, the inside dimensions of the waveguides are not scaled from one band to another. The adjustment made only a very slight change in the calculated gain (about 0.02 to 0.03 db).

The 3.95-cm horn represents an overlapping of the 3.2-cm band and the 4.75-cm band. However, it was decided to include this horn in the series because it fits a standard waveguide size (1.250 x 0.625 in. O.D.) and it provided an opportunity to make experimental checks on the 10-cm horn from which it is scaled.

The basic design data including the dimensions, operating range, and design-point gain for all the horns are summarized in Table A-2.*

Readers who are interested in a detailed design procedure are referred to the Appendix where a simple means of extending the range of Schelkunoff's gain curves and improving the accuracy of the gain figure obtainable from them is described. This method eliminates the necessity for long computations involving Fresnel integrals, and yields very close agreement with the detailed calculations.

CONSTRUCTION

As mentioned previously, the fabricated type of horn using flat metal sheets was decided upon as most suitable. The one exception is the 8-mm design, where electroforming was considered necessary because of the small size and close tolerances. Horns for the bands from 1.25 cm to 10 cm were made of brass sheets. At the 15-, 23-, and 30-cm bands, horns were fabricated from sheet aluminum using helium gas to facilitate welding the joints (heliarc process). This construction reduced the weight considerably and was found to be satisfactory for producing accurate, uniform, and rugged horns.

Dimensions for each set of horns are given in Figs. A-6 through A-17.

CALIBRATION

Experimental primary gain measurements (Fig. 2) were made in order to check the accuracy of the calculated gain.† Great care was taken in making these measurements. Both the horns and the bolometer detectors were carefully matched and the bolometer amplifier and output meter (VTVM) were calibrated accurately. The bolometer amplifier was found to be linear throughout the range used. The use of r-f coaxial cables was avoided because of instability, waveguide being used instead. Microwave absorbent material (1) was used to minimize reflections. Even so, difficulties were encountered at the longer wavelengths because of reflections and the large separation distances required. As Braun has shown (2), true Fraunhofer field conditions do not exist until a separation distance between horns of many times $2d^2/\lambda$ is attained, d being the larger aperture dimension. Because of these difficulties, experimental gain measurements at 10 cm and above were abandoned. It was decided to scale the 3.95-cm and 6-cm horns from the 10-cm horn in order to obtain reliable measurements at the shorter wavelengths. Figure 3 shows the anechoic test site. An example of the method used in evaluating the experimental data is given in the Appendix.

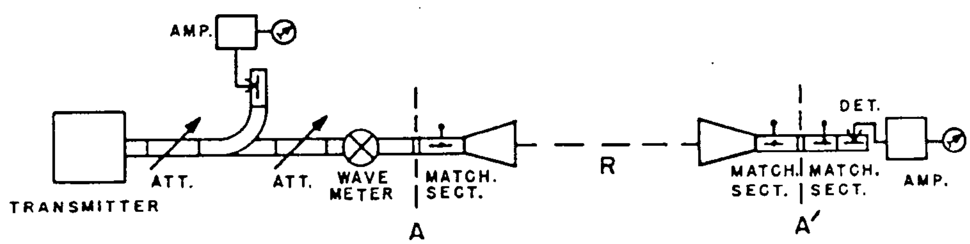

Fig. 2 - Experimental setup for gain measurements

*With the exception of Fig. A-1, all figures and tables bearing the letter A are grouped at the end of the Appendix, and are listed on page 6.

†For a general description of the methods used in making such measurements see Footno- p. 7 of the Appendix, ref. pp. 582-585. The remarks in this reference about the minimum separation distance for the horns should be re-evaluated in the light of Ref. 2.

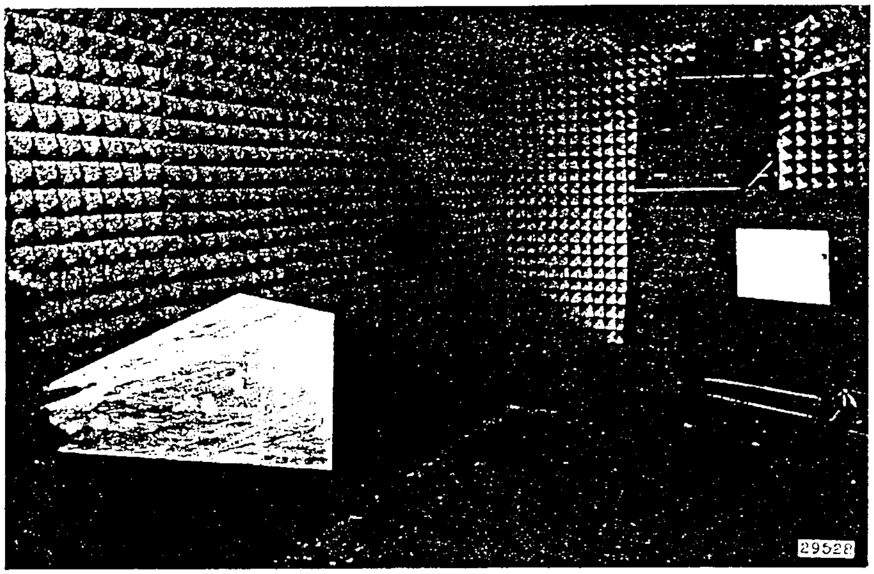

Fig. 3 - Anechoic test site

Measurements were made at several separation distances in each case, and were repeated many times, changing such variables as the power level and the peaking of the horns. See Figs. 3 and 4.

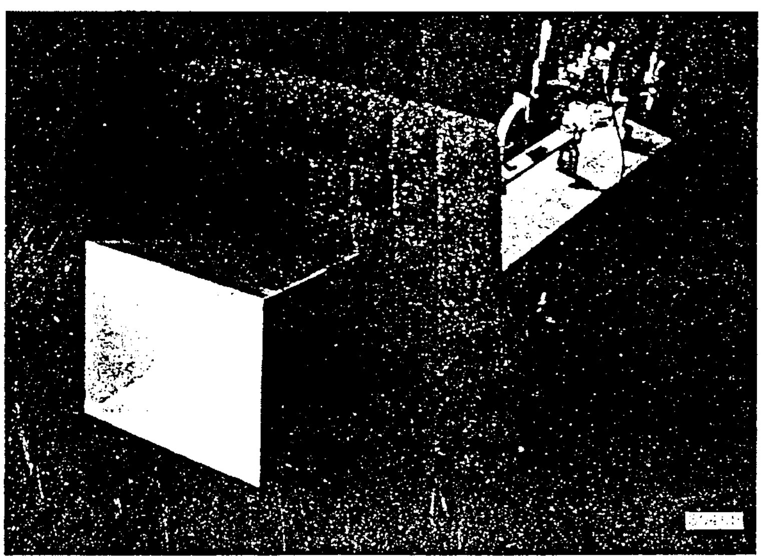

Fig. 4 - Horn and transmitter on adjustable mount

Gain curves for each band are shown in Fig. A-5 (a,b,c). Figures A-4 (a-f) show the field patterns for three basic horn designs.