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Characteristics of a Tapered Anechoic Chamber

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Prepared for BALLISTIC SYSTEMS AND SPACE SYSTEMS DIVISIONS
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California

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FOREWORD

This report is published by the Aerospace Corporation, El Segundo, California, under Air Force Contract No. AF 04(695)-1001.

This report, which documents research carried out from 15 October through 30 December 1965, was submitted on 4 January 1967 to Captain Robert D. Eaglet, SSTRT, for review and approval.

Approved

D. D. King, Director
Electronics Research Laboratory
Laboratories Division
Laboratory Operations

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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ABSTRACT

The characteristic features of a tapered anechoic chamber are described. The smooth illumination amplitude in the chamber makes it usable as an indoor range for antenna pattern measurements, even at low frequencies. Variations in the transmission attenuation in the chamber as compared to free space require careful interpretation of absolute gain and cross-section data.

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I. INTRODUCTION

Recently, a new design [1] for anechoic chambers has been developed, which offers improved performance at low frequencies. This chamber is designed in the shape of a pyramidal horn that tapers from a small illuminating end to a large rectangular test region. The salient features of this type of chamber can be explained qualitatively by ray optics.

The purpose of this note is to point out some of the inherent properties of tapered anechoic chambers. Some experimental data showing a comparison between the transmission characteristics of a tapered chamber and free space are presented.

There are two effects in a tapered chamber that can limit its ultimate performance as an indoor range. First, there is a deviation from the $1/R^2$ dependence, and, second, there is an apparent decrease or increase of signal strength as compared to free-space transmission. The variations in transmission loss between the tapered chamber and free space become more significant in situations where low-directivity antennas are employed, i.e.,

[1] W. H. Emerson and H. B. Sefton, "An Improved Design for Indoor Ranges," Proc. IEEE, vol. 53, pp. 1079-1081, August 1965.

at low frequencies. At high frequencies, high-gain antennas are generally used, and the effect of the chamber on the operation will be correspondingly less. For this reason, our discussions will be concerned largely with low-frequency operations.

II. DISCUSSION

In a practical operation of the tapered chamber, the transmitting antenna aperture is usually placed at a small distance from the apex. Thus, multipath effects [2] also exist inside the tapered chamber as in a conventional rectangular chamber. The situation is illustrated in Fig. 1. By ray tracing techniques, one can establish that there is very little change in path and reflection phase differences among the direct ray and singly reflected rays at any point in the target region of the tapered chamber. These rays vectorially add to create a slowly varying spatial interference pattern; whereas, in the rectangular chamber, the changes in path and reflection phase differences are larger and a more rapidly varying spatial pattern results. This explains the smooth illumination amplitude in the target region of the tapered chamber as compared to that of a rectangular chamber [1]. A smoother illumination amplitude makes a chamber more suitable for antenna pattern and radar cross section measurements.

The presence of multipath effects implies that the chamber does not simulate free-space environment exactly since the power density in the chamber will deviate from the $1/R^2$ dependence, the magnitude of deviation being dependent upon the path difference and the reflection coefficient at the walls. In a tapered chamber, the spatial frequency of the standing wave pattern is difficult to detect because of the small change in the total phase differential between the direct and reflected rays. Consequently, one would have to probe a long distance to observe multipath effects. In a rectangular chamber, the standing wave

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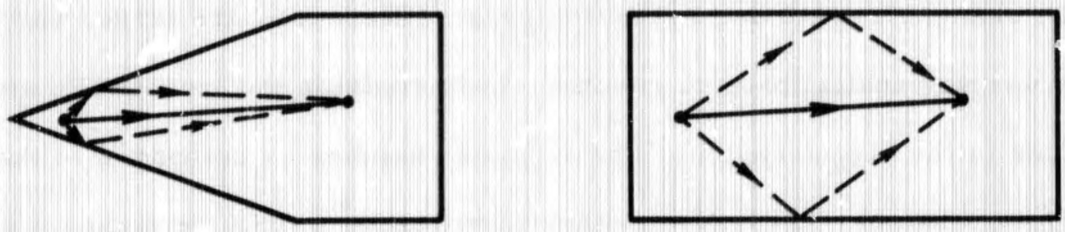
[2] This is in contrast to the idealized situation, where the sources of energy are assumed to be emanating from a single point at the apex, which predicts no multipath effects.



(a) TAPERED CHAMBER (b) RECTANGULAR CHAMBER

Fig. 1. Comparison of chambers.

pattern is detected easily because of the relatively large change in the phase difference between the direct and reflected rays in the target region. However, it should be mentioned that in rectangular chambers, higher quality absorbing materials are usually placed at the specular points and the magnitude of the reflection coefficient will be less.

In any quantitative analysis, one must take into account the reflection coefficient and its accompanying phase, the fact that two of the walls will reflect polarizations in quadrature with respect to the other two walls, and the characteristics of the transmitting antenna. However, a few observations can be made. In a tapered chamber, the change in phase differential between the direct and reflected rays can be minimized by placing the transmitting antenna as close as possible to the apex and on the axis of the chamber. Also the direct and singly reflected rays will be nearly parallel, resembling more closely those of a uniform plane wave. On the other hand, doing this will increase the near-field coupling losses. This effect will be shown in the next section. Also, if ray optics give an accurate characterization of the chamber, one should be careful in interpreting antenna radiation patterns and radar cross section data because of the presence of multipath.

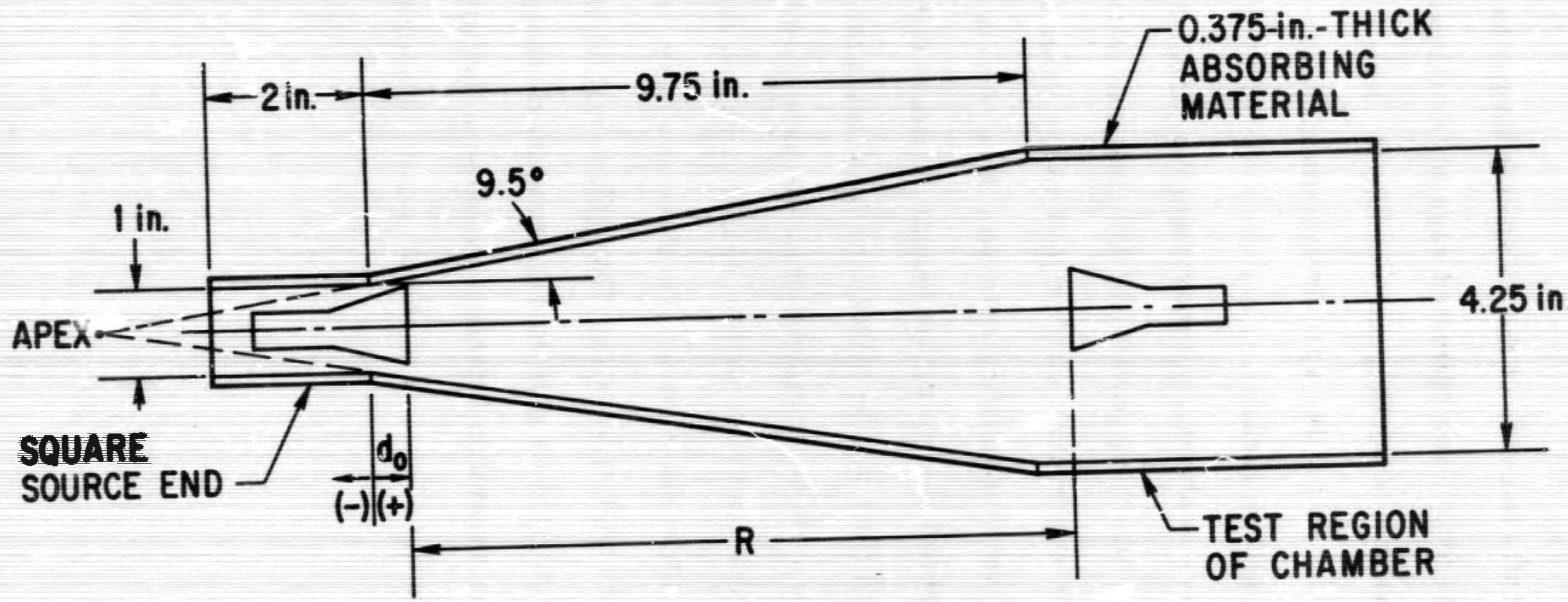


Fig. 2. Scaled model of tapered anechoic chamber.

III. EXPERIMENTAL INVESTIGATIONS

A scaled model of a typical tapered chamber was constructed from 0.375-in.-thick smooth-surfaced absorbing material [3]. The dimensions are shown in Fig. 2. Although this model has a small rectangular source end, which is a slight deviation from the usual tapered chamber, it is sufficiently accurate for the purpose of our present investigations. For typical low-frequency operations, the opening at the source end may be in the order of a wavelength. Two low gain, sectoral E-plane horns, with a 0.900 × 0.900-in. aperture, flared directly from WR 90 waveguides (0.400 × 0.900-in.) were used as transmitting and receiving antennas.

The two horns first were placed in a free-space conventional antenna pattern setup and plots of relative attenuation vs distance were made. The measurements then were repeated inside the chamber with the same test setup, receiver-gain level, and transmitter power. In this manner, the relative transmission loss of the chamber with respect to that of free space is determined.

Figures 3 and 4 are typical plots for the case where the transmitting antenna is 0.8 in. from the throat, at the throat, and 0.8 in. behind the throat. This is the distance d_0 shown in Fig. 2. The $1/R^2$ line represents the case with the horns in free space. The curves for the cases with the horns inside the chamber are normalized with respect to the $1/R^2$ line. From these plots it is observed that either an increase or a decrease in

[3] Emerson and Cuming, Type AN-73.

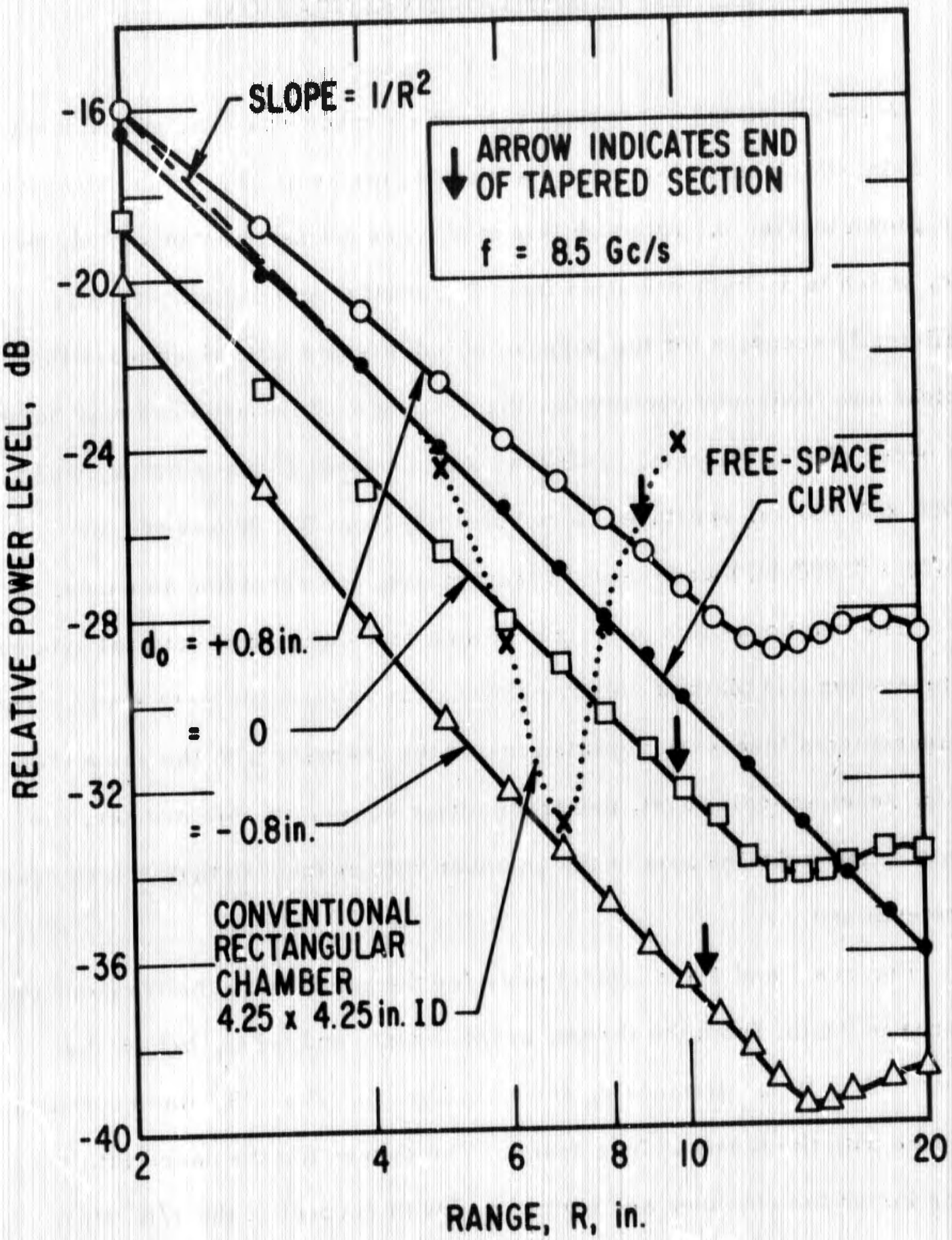


Fig. 3. Field strength characteristics of a tapered chamber relative to free space, scaled frequency 8.5 Gc/s.

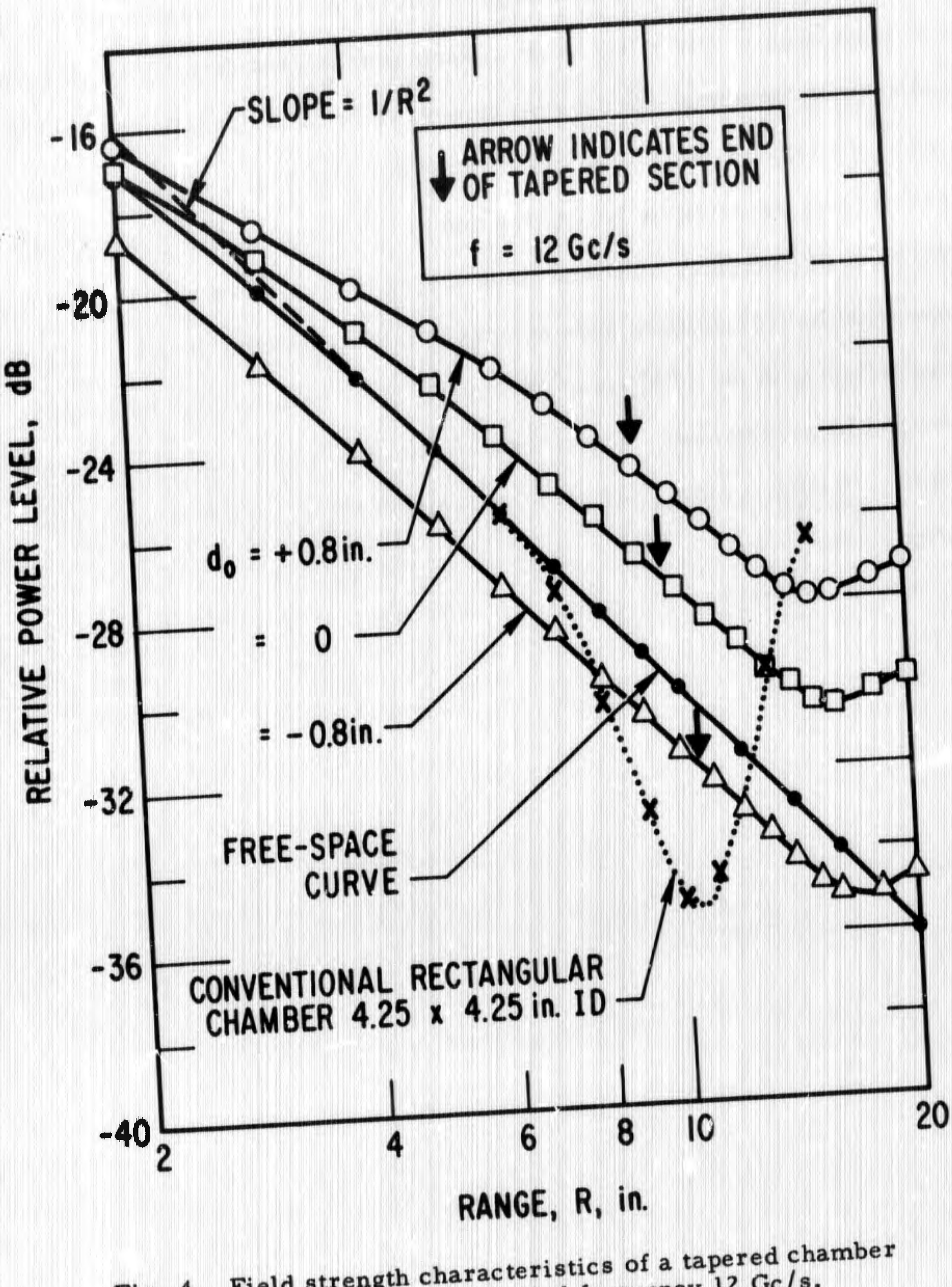


Fig. 4. Field strength characteristics of a tapered chamber relative to free space; scaled frequency 12 Gc/s.

signal strength is possible as compared to the measured values in free space. The magnitude of this effect is dependent upon antenna directivity, frequency, and antenna location. All curves are seen to be fairly parallel to the $1/R^2$ line in the tapered portion of the chamber and in a region approximately three to five wavelengths beyond the end of the taper — the usual useful range of a tapered chamber. A comparison among these curves reveals that the case with the transmitting horn antenna placed behind the throat is in better parallelism with the $1/R^2$ line. However, at the same time, the coupling loss has increased also. The measured curves for the case of a rectangular chamber model, constructed with the same material, are also shown for comparison.

IV. CONCLUSIONS

(1) Multipath effects exist in tapered chambers. The change in the phase differential between the direct and the singly-reflected rays across the chamber is small. The magnitude of the energy being carried by the reflected rays depends upon the particular operating environment, i.e., chamber shape, quality of the absorbing materials, antenna directivity, etc.

(2) The smooth illumination amplitude in a tapered chamber makes it more suitable for radiation pattern measurements utilizing low gain antennas.

(3) The variations in transmission loss between the tapered chamber and free space prevent the making of absolute gain measurements of antennas.

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