The Antenna Laboratory

Department of Electrical Engineering

A TECHNIQUE FOR MEASURING THE SCATTERING APERTURE
AND ABSORPTION APERTURE OF AN ANTENNA

by

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Contract AF 30(635)-2811

ROME AIR DEVELOPMENT CENTER
Griffiss Air Force Base, New York

612-15

1 January 1957

The Ohio State University
Research Foundation
Columbus, Ohio

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REPORT

by

THE OHIO STATE UNIVERSITY RESEARCH FOUNDATION
COLUMBUS 10, OHIO

Cooperator	Rome Air Development Center Griffiss Air Force Base, New York
Contract	AF 30(635)-2811
Investigation of	Landing System Problems
Subject of Report	A Technique for Measuring the Scattering Aperture and Absorption Aperture of an Antenna
Submitted by	J. A. McEntee Antenna Laboratory Department of Electrical Engineering
Date	1 January 1957

ABSTRACT

A simple technique, employing echo-area measuring equipment, has been developed to measure the absolute values of the scattering aperture and absorption (effective) aperture of an antenna with a short-circuited feed.

The technique has been applied to an optimum pyramidal horn and the results are correlated with theoretical considerations found in the literature.

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A TECHNIQUE FOR MEASURING THE SCATTERING APERTURE AND ABSORPTION APERTURE OF AN ANTENNA

by

J. A. McEntee

I. INTRODUCTION

An investigation of the scattering characteristics of certain classes of antennas and reflectors as passive echo-enhancing devices for use in Ground-Controlled Approach (GCA) systems is being conducted.[1] As one result, a simple technique has been developed for measuring the absolute value of the absorption (effective) aperture and the scattering aperture of antennas using echo-area measuring equipment.

II. TECHNIQUE

In general, the scattering characteristics of an antenna cannot be completely formulated in terms of a simple equivalent series circuit,[2] nor can they be determined completely from the radiation characteristics of the antenna. For example, if the antenna is terminated in an arbitrary impedance, the total back-scattered signal can be considered as the superposition of the signal scattered from the antenna structure, which is independent of the terminal conditions, and the signal due to reflection from this terminal impedance if it is not matched to the feed line. That is,

(1) $$E_T = E_s + E_a\, e^{j\Phi}$$

where

E_T = total scattered signal

E_s = signal scattered from the structure

E_a = scattered signal due to reflection from the termination

Φ = relative phase.

E_s, E_a, and Φ are functions of the aspect angle (θ and ϕ in the conventional spherical coordinate system). In addition, E_a and Φ are functions of the terminating impedance Z_T; in particular, if $Z_T = Z_o$, then $E_a \equiv 0$. Hence the total scattering pattern is a function of the terminal impedance.

If a moving short circuit can be placed in the feed line, then at any aspect a maximum and minimum total scattered signal can be obtained. That is,

(2) $$|E_{max}| = |E_1| + |E_2|$$

and

(3) $$|E_{min}| = |E_1| - |E_2|$$

where E_1 and E_2 represent the scattered and reradiated signals. From relationships (2) and (3) it follows that

(4) $$\frac{E_1}{E_{max}} = \frac{1}{2}\left(1 + \frac{E_{min}}{E_{max}}\right) ,$$

and

(5) $$\frac{E_2}{E_{max}} = \frac{1}{2}\left(1 - \frac{E_{min}}{E_{max}}\right) .$$

These relations (4) and (5) are given in graphical form in Fig. 4, as a function of E_{min}/E_{max}.

The squares of (4) and (5) are relative echo areas which can be measured. That is,

(6) $$\frac{\sigma_1}{\sigma_{max}} = \left(\frac{E_1}{E_{max}}\right)^2$$

and

(7) $$\frac{\sigma_2}{\sigma_{max}} = \left(\frac{E_2}{E_{max}}\right)^2 .$$

One is the equivalent echo area (σ_s) of the scattered signal which we will define as being related to the scattering aperture (A_s). That is,

(8) $$\sigma_s = \frac{4\pi A_s^2}{\lambda^2} ,$$

if in turn a scattering gain is defined as

(9) $$g_s = \frac{4\pi A_s}{\lambda^2} .$$

The other is the equivalent echo area (σ_ϵ) of the reradiated signal which is similarly related to the effective aperture.

$$(10) \qquad \sigma_\epsilon = \frac{4\pi A_\epsilon^2}{\lambda^2} \quad .$$

The identification or sorting out of the echo areas can be resolved by replacing the short circuit with a matched load. The echo response now consists only of the signal scattered from the structure since the signal which would be reradiated is completely absorbed in the load.

The absolute value of the maximum response (σ_{max}) can be determined precisely by using a standard target of known echo area. We will define relative echo area (σ) in decibels as equal to 10 $\log_{10}(\sigma_a / \sigma_b)$.

From the above definitions, then,

$$(11) \qquad A_\epsilon = \left(\frac{\lambda^2 \sigma_\epsilon}{4\pi}\right)^{\frac{1}{2}}$$

and

$$(12) \qquad A_s = \left(\frac{\lambda^2 \sigma_s}{4\pi}\right)^{\frac{1}{2}} \quad .$$

The gain of the antenna can be determined as a by-product of this technique from the relation

$$(13) \qquad \text{gain} = \frac{4\pi A_\epsilon}{\lambda^2} \quad .$$

Note that on the basis of the above definition the scattering aperture and the absorption aperture are not necessarily equal, as predicted by the simple equivalent series circuit representation, when the feed line and termination are matched to the antenna. This is true because it is too restrictive in that all of the current flows through the equivalent antenna impedance (which represents scattered power) and the load impedance (which represents absorbed power), and this is not the usual situation in practice.

III. MEASUREMENTS

This technique was applied to an optimum pyramidal horn. The measurements were taken in an indoor anechoic chamber using a cw reflection measuring system.[3]

The diagram below, Fig. 1, indicates the significant dimensions of the horn antenna.

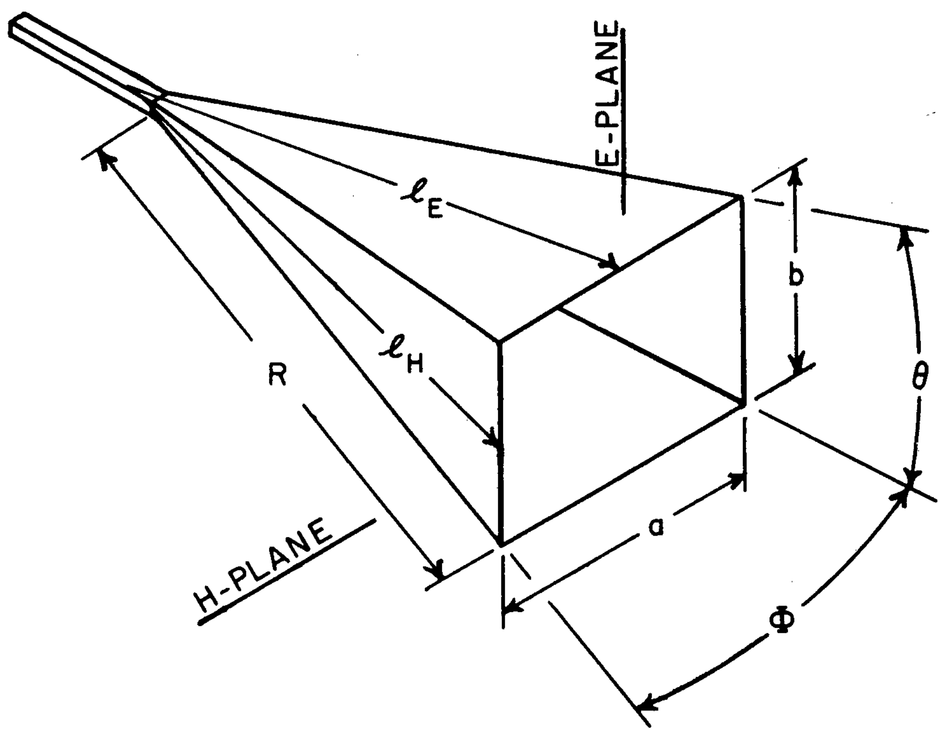

Fig. 1. Horn dimensions.

The results are shown below:

HORN DIMENSIONS:	RESULTS:
ℓ_E - 7.45" = 5.73λ	A_p = ab = 1.81×10^{-2} meters^2
ℓ_H - 8.18" = 6.30λ	σ_ϵ = 0.77 meters^2
θ - $37\frac{1}{2}^\circ$	σ_s = 0.57 meters^2
Φ - 42°	A_ϵ = 0.82×10^{-2} meters^2
a - 5.88" = 4.52λ	A_s = 0.71×10^{-2} meters^2
b - 4.77" = 3.67λ	G = 94.7 or 19.8 db ($\pm$0.1 db)
R - 7.27" = 5.59λ	A_ϵ/A_p = 45.3%
λ - 3.30 cm	A_s/A_p = 39%
	A_ϵ/A_s = 1.16

The gain (directivity) of an optimum pyramidal horn with the above physical dimensions can be calculated using theoretical considerations found in the literature.[4,5] From this value of gain, the effective aperture can be calculated from (13). Using the theoretical considerations the calculated gain was 19.76 db.

Figure 2 shows the echo-area patterns of the horn under test as a function of azimuth. Figure 3 is the radiation pattern of the horn in the H-plane which is identical to the echo pattern due to the reradiated signal.

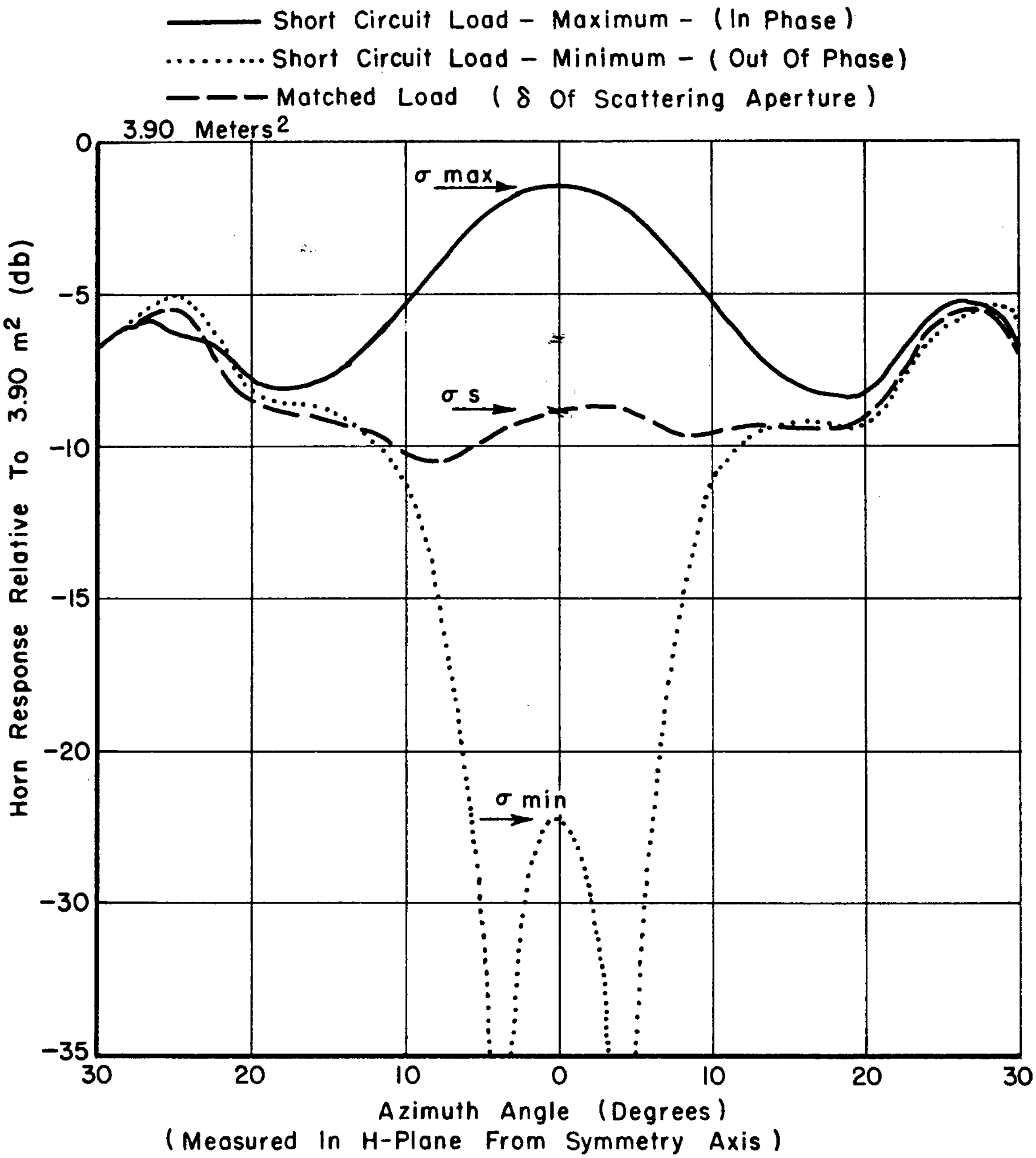

Fig. 2. H-plane echo-area patterns of a pyramidal horn with various loads. Frequency = 9080 mc.

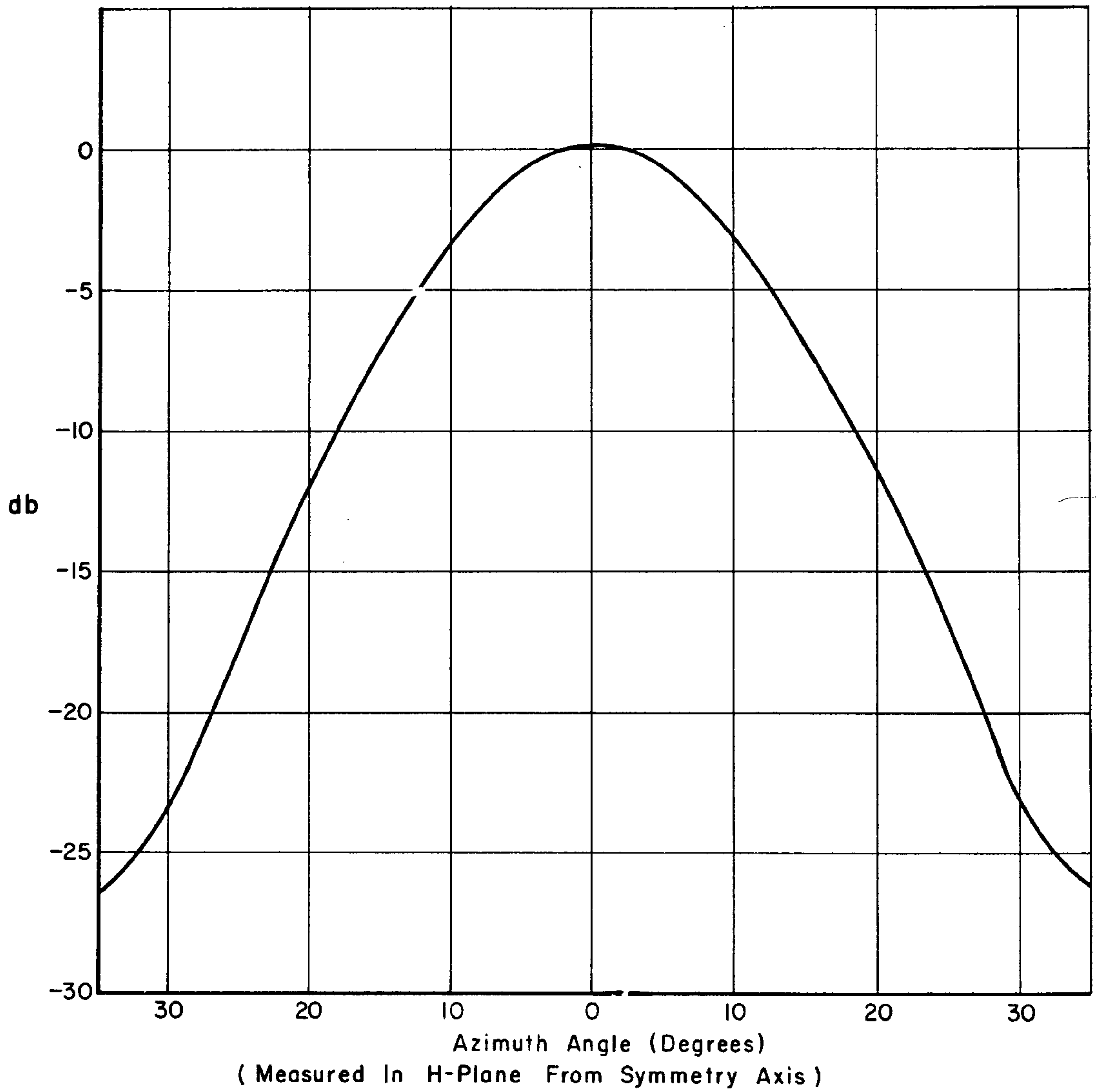

Fig. 3. Radiation pattern of optimum pyramidal horn in H-plane. Frequency = 9080 mc.

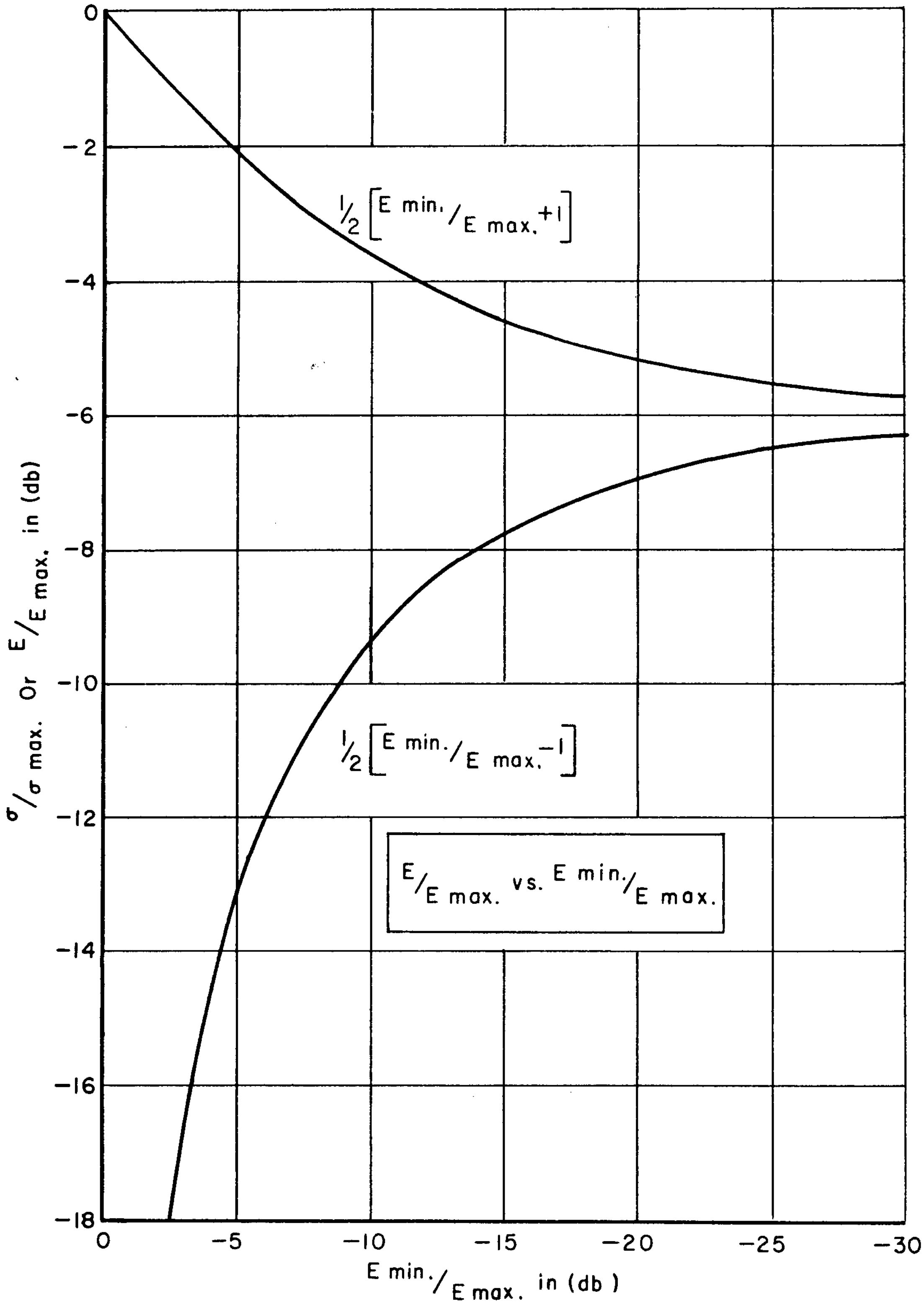

Fig. 4. Echo area relative to σ_{max} as function of E_{max}/E_{min}.

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