H-plane radiation patterns of a dipole antenna mounted above a finite rectangular ground screen

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ABSTRACT

A simple, accurate method is presented for calculating the H-plane radiation pattern of a dipole antenna mounted parallel to a finite rectangular ground screen. The solution is valid for ground screens which are large in the dimension parallel to the dipole. The H-plane radiation pattern of the antenna is predicted from an approximate solution for the field of an electric line source parallel to a perfectly conducting strip of infinite length and finite width. A simple solution of the strip problem is obtained which is useful for all but very narrow strips.

Computed patterns are presented for a wide range of ground plane widths and dipole spacings. Comparisons with experimental results indicate that the solution is accurate for the complete range of parameters of engineering interest.

CONTENTS

FIGURES

H-PLANE RADIATION PATTERNS OF A DIPOLE ANTENNA MOUNTED ABOVE A FINITE RECTANGULAR GROUND SCREEN

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Introduction

In the design of antennas with linear radiating elements, the problem of determining the radiation pattern of a dipole antenna mounted above a ground screen of finite dimensions is often encountered. An analytical solution of the problem is, in general, either impossible or extremely complex but some special cases admit relatively simple analyses. The present report deals with the class of dipole – ground screen antennas whose H-plane radiation patterns may be approximated by those of an electric line source parallel to a perfectly conducting strip of infinite length and finite width. By applying super-position, an array of dipoles above a ground screen may also be treated.

Several methods have been employed to calculate the radiation of a line source parallel to a strip. An exact solution in the form of an infinite series of Mathieu functions is known, but the series converges slowly unless the strip is narrow. The physical optics approximation has been applied to the problem [1], but the resulting integrals cannot in general be evaluated in closed form. The geometrical theory of diffraction in its most elementary form provides a simple solution but does not properly describe shadow boundary regions.

Analysis

In the present report an approximate solution of the strip problem is obtained by superimposing exact solutions for the field of a line source parallel to a conducting half-plane. With reference to Fig. 1, the radiation field of the source in the presence of a half-plane extending from $x=-w/2$ to $x=+\infty$ is added to that of the source in the

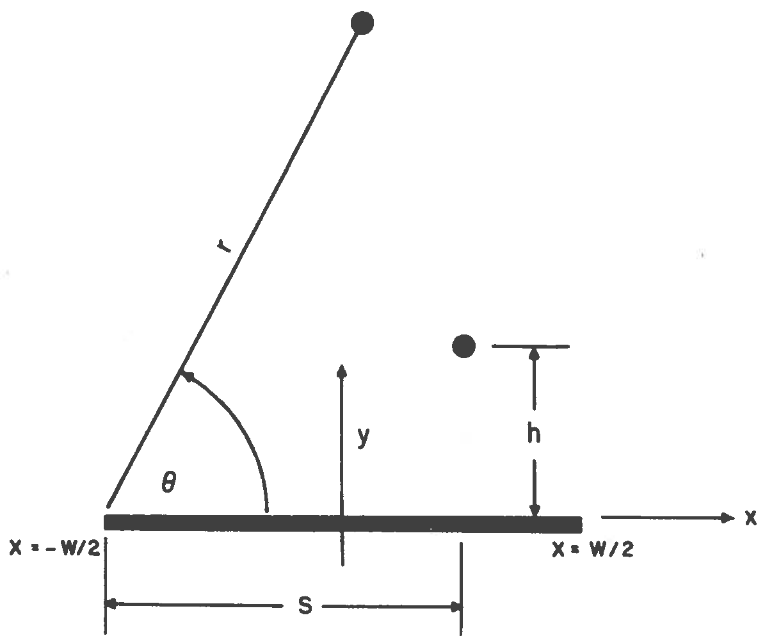

Figure 1 An electric line source above a perfectly conducting strip

presence of a half-plane extending from $x = w/2$ to $x = -\infty$. The field of the source in the presence of a conducting plane extending from $x = -\infty$ to $x = +\infty$ is subtracted from this result to yield an approximate solution for the field of the source in the presence of a wide strip. The required half-plane solutions and hence the approximate strip solution can be simply expressed in terms of Fresnel integrals [2].

For the geometry of Fig. 1, the above procedure yields the following approximation to the far zone electric field for unit source strength excitation of the strip.

$$E = E_1 + E_2 + E_3$$

where

$$E_1 = \frac{e^{ikr}}{\sqrt{r}} f(s, h, \theta) \qquad 0 < \theta < 2\pi$$

$$E_2 = \frac{e^{ik(r - w\cos\theta)}}{\sqrt{r}} f(w - s, h, \pi - \theta) \qquad 0 < \pi - \theta < 2\pi$$

$$E_3 = 2i \sin(kh \sin\theta) \frac{e^{ik(r - s\cos\theta)}}{\sqrt{r}} \qquad 0 < \theta < \pi$$

$$= 0 \qquad \pi < \theta < 2\pi$$

and

$$f(a,b,\theta) = \frac{e^{-i\pi/4}}{\sqrt{\pi}} \left[e^{-ikd\cos(\theta-\gamma)} F\left(-\sqrt{2kd}\cos\frac{(\theta-\gamma)}{2}\right) - e^{ikd\cos(\theta+\gamma)} F\left(-\sqrt{2kd}\cos\frac{(\theta+\gamma)}{2}\right) \right]$$

with $\tan\gamma = b/a$

and $d = b/\sin\gamma$.

The functions denoted F are Fresnel integrals defined by

$$F(u) = \int_u^\infty e^{ix^2} dx$$

It can be verified that this approximate solution is equivalent to applying the geometrical theory of diffraction with modified diffraction coefficients and neglect of multiple edge interactions. Consequently, the present analysis neglects terms $0(kw)^{-1.5}$ where w is the strip width and $k = 2\pi/\lambda$. The solution obeys the wave equation and the boundary condition for the tangential electric field exactly, but only approximates the condition that the tangential magnetic field be continuous on $y = 0$, $|x| > w$ (Fig. 1).

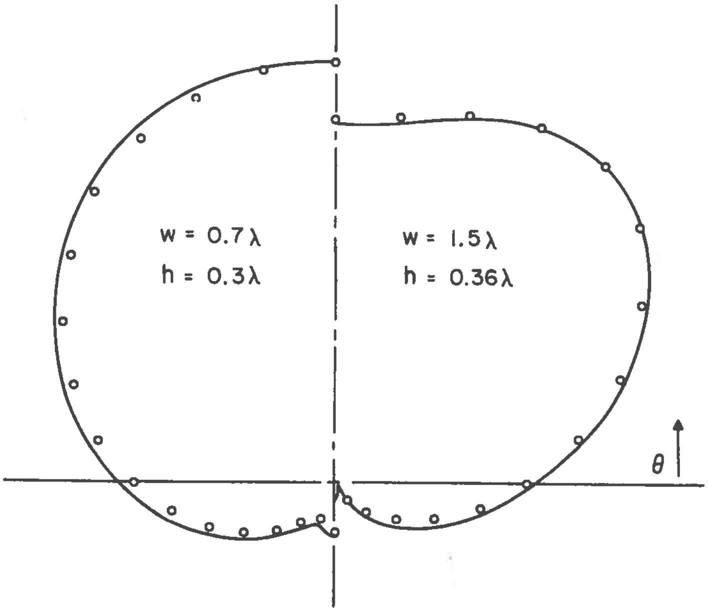

Figure 2 Theoretical (○) and experimental field strength patterns for symmetric excitation

Results

Figures 2 and 3 show a comparison of patterns predicted by the present analysis and those obtained experimentally. In Fig. 2 two patterns are shown for symmetrically located sources and Fig. 3 shows a pattern obtained for asymmetric excitation. In all cases discrepancies of the theoretical and experimental values are well within experimental errors.

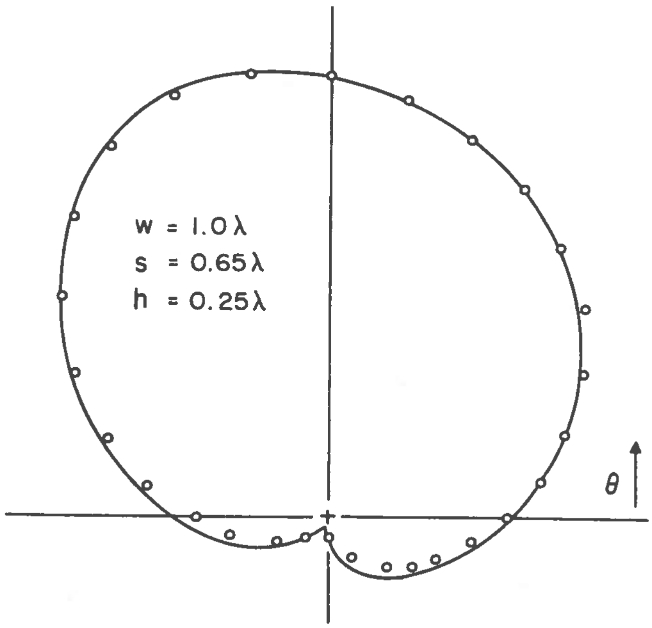

Figure 3 Theoretical (○) and experimental field strength patterns for asymmetric excitation

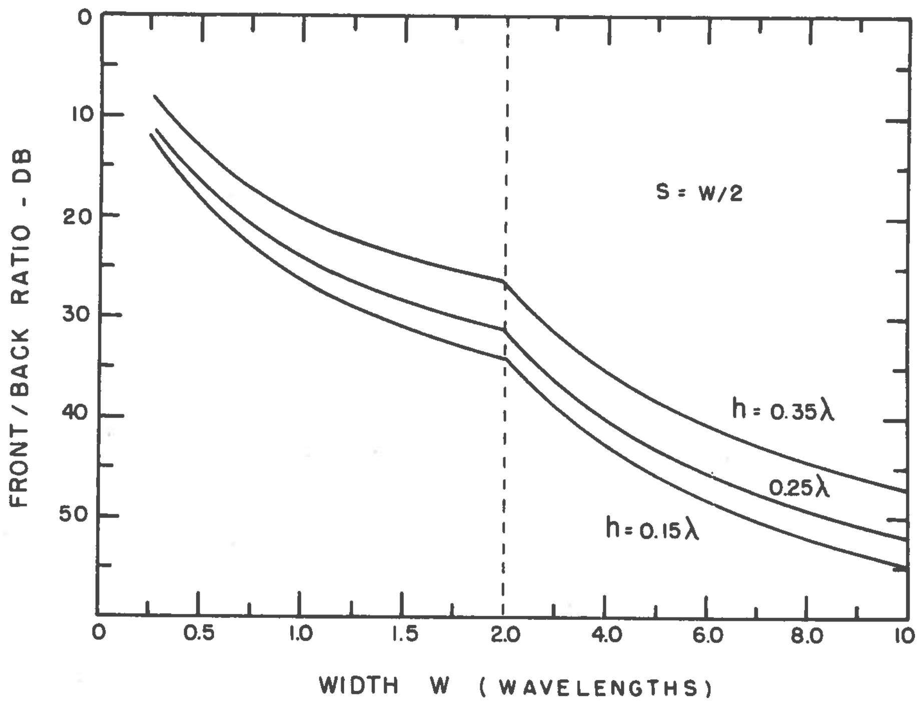

Figure 4 Front to back ratio vs. ground plane width for three dipole spacings

Figure 4 shows the calculated front-to-back ratio as a function of ground plane width for three spacings of symmetrically located dipoles. Figures 5 to 7 show patterns obtained for dipoles placed symmetrically 0.15λ, 0.25λ, and 0.35λ above ground planes of widths 0.25, 0.5, 0.75, 1.0, 1.5, 3.0, 6.0, and 10 wavelengths. For comparison, results are also given for dipoles above an infinite ground plane.

Conclusions

A straightforward method has been presented for calculating the H-plane radiation pattern of a dipole antenna mounted above a finite rectangular ground screen. A series of calculated patterns have been presented to overcome an apparent lack of adequate design data in the existing literature.

References

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2. Born, M. and Wolfe, E. Principles of optics. Pergamon Press, p. 580, 1965.

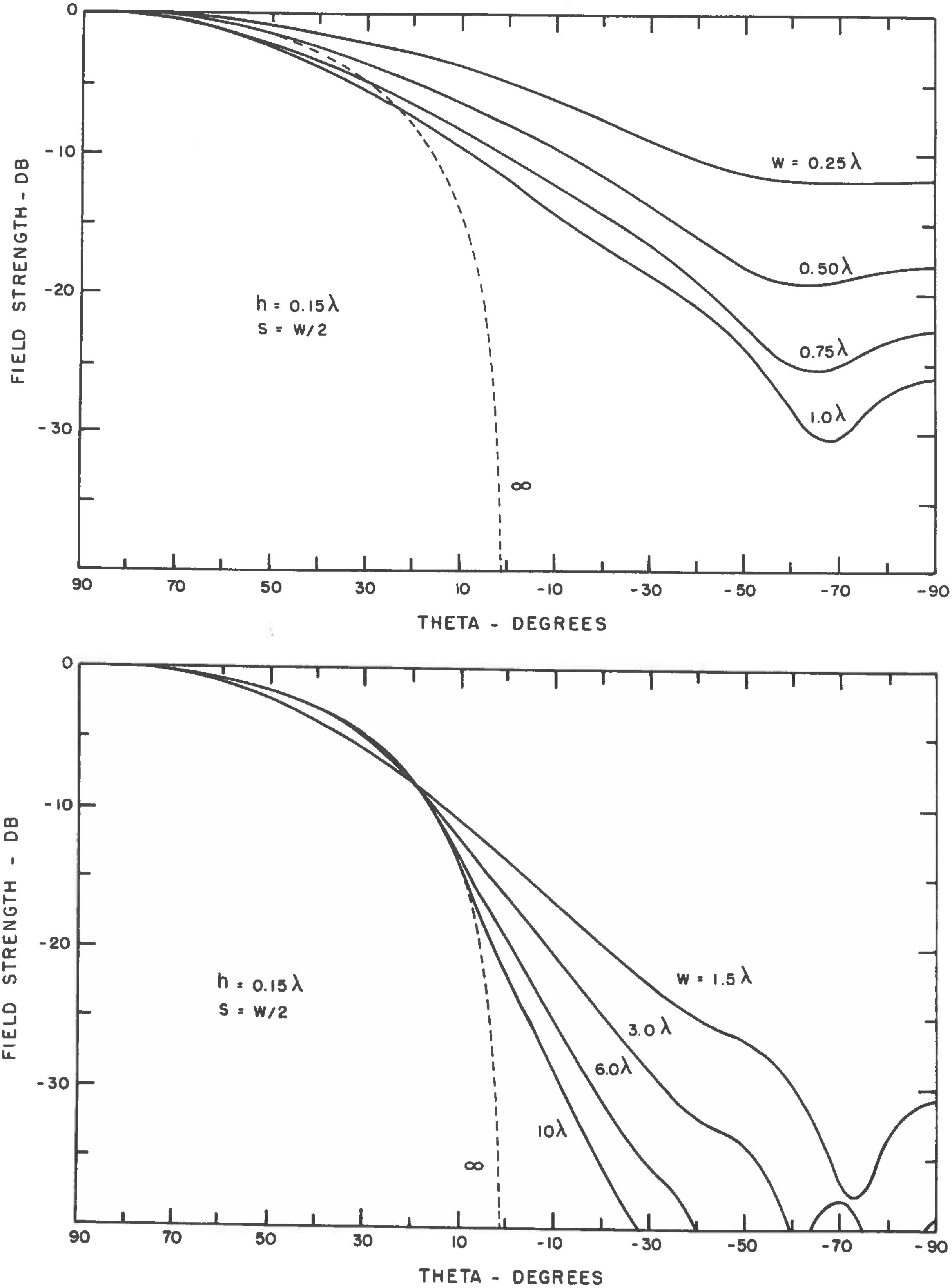


Figure 5 H-plane patterns of a dipole antenna mounted above ground planes of various widths

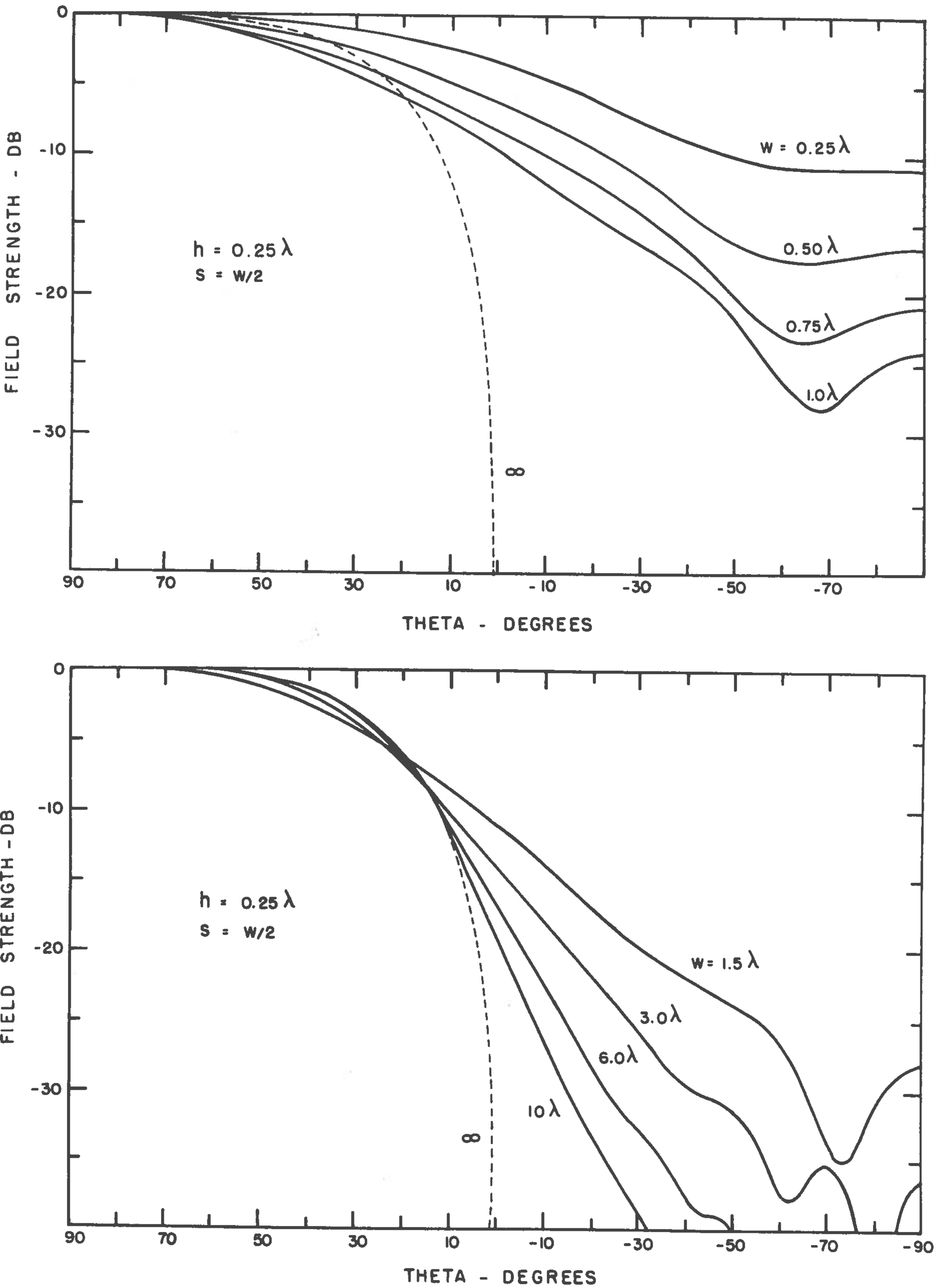
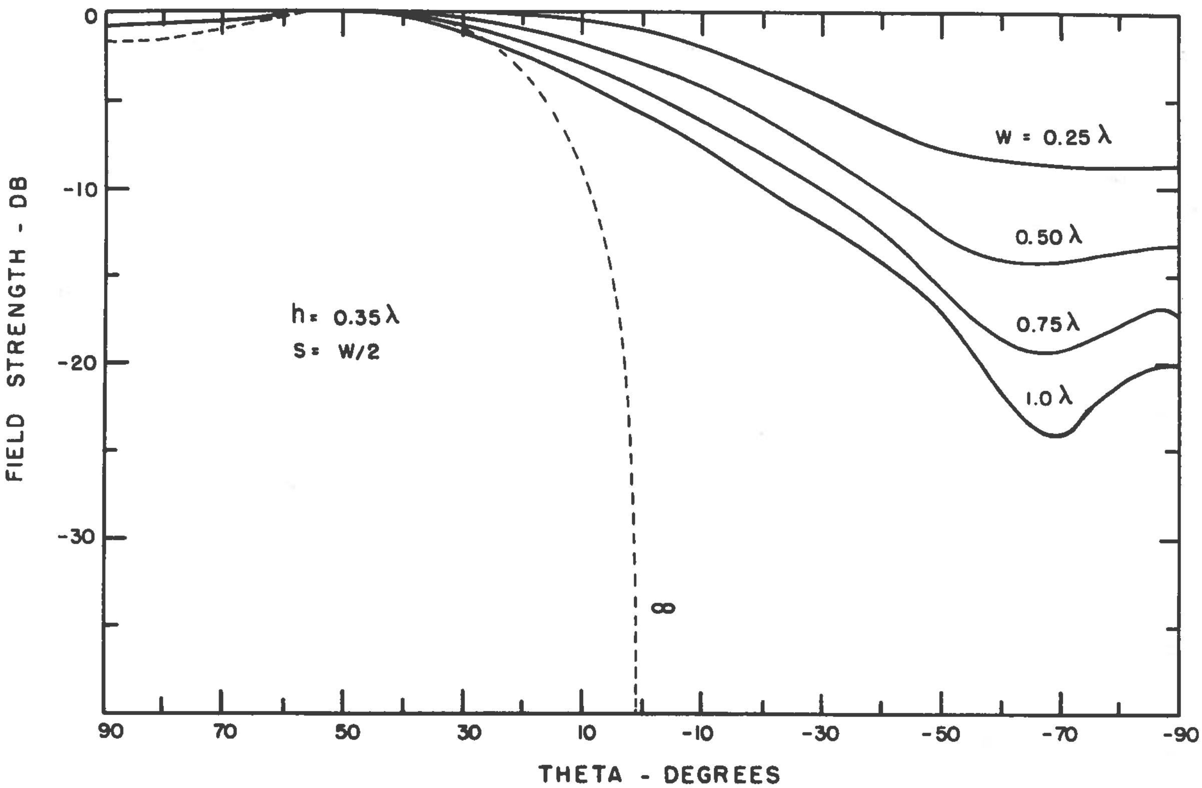


Figure 6 H-plane patterns of a dipole antenna mounted above ground planes of various widths



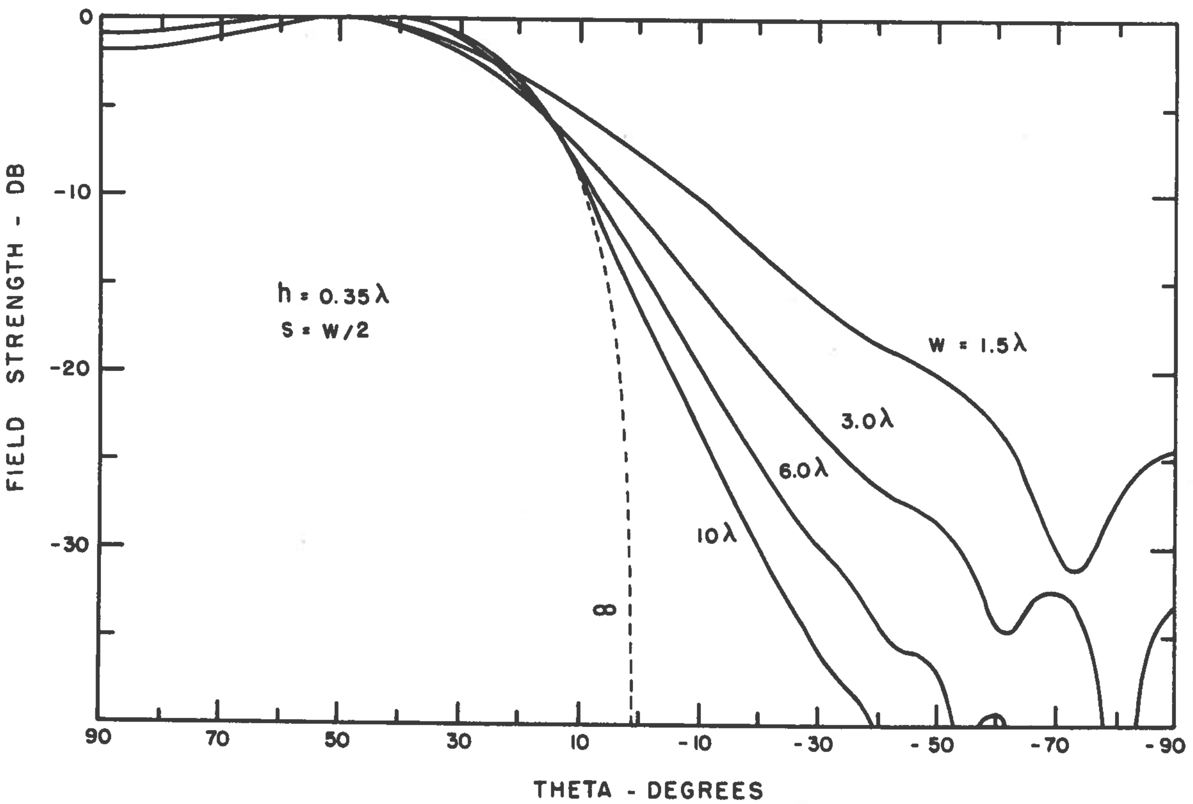


Figure 7 H-plane patterns of a dipole antenna mounted above ground planes of various widths