ANALYSIS OF AIRBORNE ANTENNA PATTERNS

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16. Abstract (Limit: 200 words)

This is a summary of the research accomplishments for the reporting period July, 1981 to January, 1982. The achievements in numerically modeling the radiation patterns for antennas mounted on private aircraft are our major objectives.

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I. INTRODUCTION

This effort is composed of several research topics which are proceeding in parallel. The major research area is the development of numerical methods (computer codes) to analyze the radiation patterns for antennas mounted on general aircraft with specific interest in private aircraft simulations. We are presently developing a computer code to analyze private aircraft assuming that the structure is perfectly conducting and large in terms of the wavelength. Based on earlier studies, we found that the windshield of a private aircraft scatters a significant amount of energy; however, it can not be approximated as a perfect conductor [1]. As a result, we have been developing a method to treat the high frequency scattering by thin dielectric layers [2]. These solutions have been based on a modification of the perfectly conducting half plane solution which lacks a rigorous analysis. This has led us to theoretically analyze the scattering from a thin dielectric layer. One should note that this is a joint effort between this project and the Joint Services Program (Contract No. 710816) with the ElectroScience Laboratory.

In order to treat private aircraft at lower frequencies, i.e., where the aircraft surface area is less than 10 square wavelengths, we have been modifying a moment method code. The moment method compliments the high frequency solutions already being developed and should provide excellent results for the lower frequencies. This effort is just beginning at this time.

II. MOMENT METHOD SIMULATION OF PRIVATE AIRCRAFT

We will now briefly describe the effort to compute the patterns of simple monopoles on small private aircraft. A method of moments solution will be employed where the aircraft is modeled by an interconnection of polygonal plates, and the monopole is modeled as a thin wire. The model for a Cessna 150 is shown in Figure 1. It consists of 23 interconnected plates. The wing span of the plane is about 4λ at 121 MHz, and 345 surface patch dipole modes are employed. At present we are in the final stages of code development to compute the radiation from this aircraft.

III. DIFFRACTION BY A THIN DIELECTRIC HALF-PLANE

The diffraction by a thin dielectric half plane is an important canonical problem in the study of the diffraction of electromagnetic waves by penetrable bodies with edges. The excitation for this problem can be either an electromagnetic plane wave, or a surface wave incident along the dielectric surface; both types of excitation are considered. For sufficiently thin dielectric half planes, solutions based on the Wiener-Hopf technique can be obtained if one approximates the effect of the thin dielectric slab by an impedance boundary condition. This analysis begins by bisecting the semi-infinite dielectric half plane by an electric wall in the first case, and by a magnetic wall in the second case. The problem of plane (or surface) wave diffraction by the dielectric half plane is then constructed by appropriately superimposing

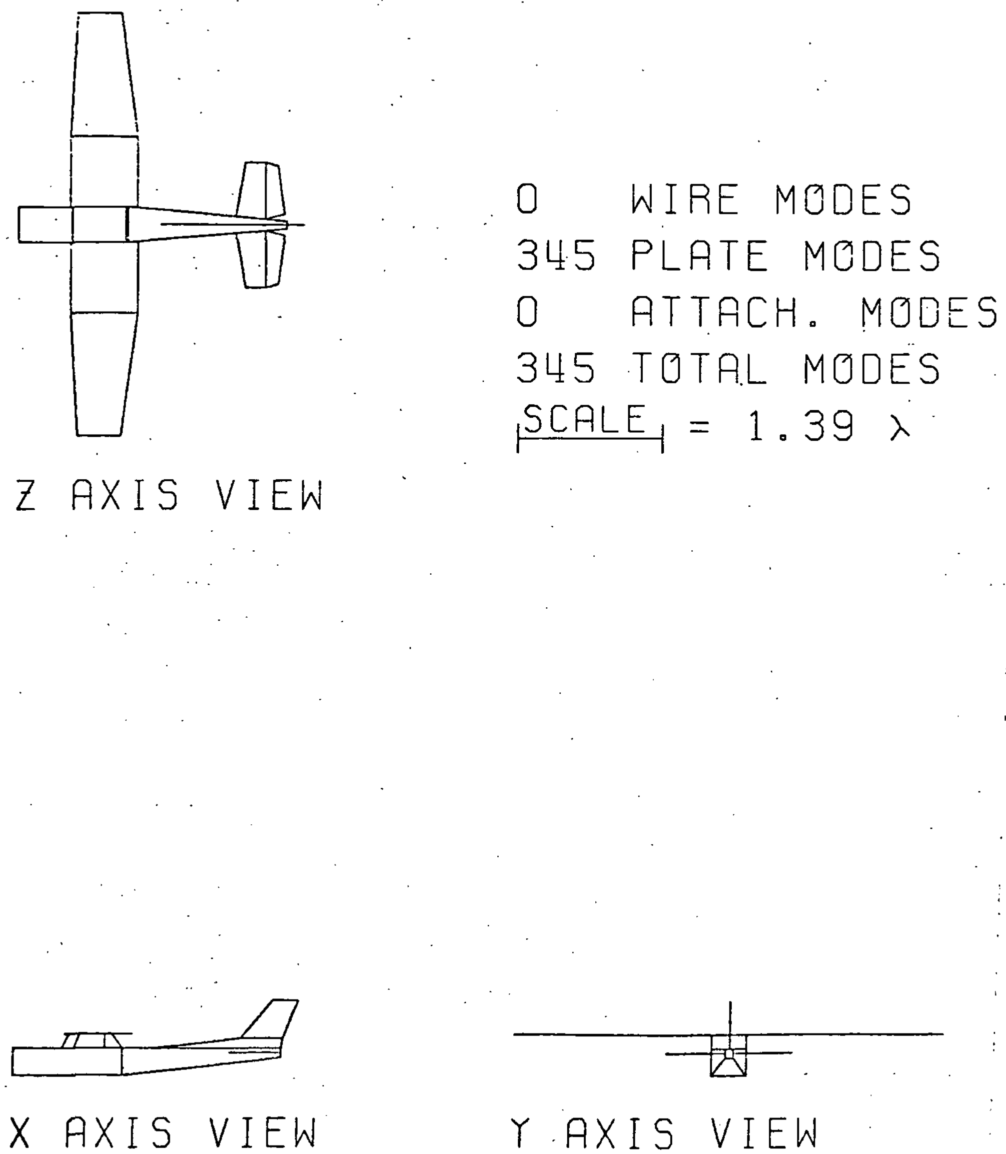

Figure 1. Model for Cessna 150.

the corresponding solutions for the electric and magnetic wall bisections, respectively. This procedure is expected to yield a dielectric half plane diffraction coefficient which is far more accurate than that obtained recently by Anderson for the case when the incident plane wave electric field is parallel to the edge of the thin dielectric half plane [3], because the latter analysis employs an approximate "equivalent" polarization current sheet model for the thin dielectric half plane. The approximation in [3] contains only a part of the information present in the more general approach being employed in our work; consequently, it is found that the analysis in [3] yields a diffraction coefficient which is valid only for an extremely thin dielectric half plane. Furthermore, the equivalent polarization current approximation leads to a more complicated Wiener-Hopf analysis when the magnetic field is parallel to the edge; the latter case has not been treated by Anderson [3]. It is also noted that the Wiener-Hopf factors for the case treated by Anderson [3] do not appear to be well behaved for the near edge on plane wave incidence case. In contrast, the Wiener-Hopf factors being employed in our work are based on Weinstein's factorization procedure [4] which overcomes the difficulties present in [3].

At the present time, the diffraction coefficients for the two dimensional case for both TE and TM plane, cylindrical, and surface wave excitations of the thin dielectric half-plane have been obtained, and they are being tested for accuracy as indicated on the next page.

The accuracy of the new diffraction coefficients have been tested thus far by calculating the radiation patterns for the two-dimensional geometry shown in Figure 2 using our thin dielectric half-plane diffraction coefficients, and by comparing these results with those obtained independently via the moment method.

Since the width of the dielectric strip depicted in Figure 2 is 2λ or 1λ depending on which source is used, (2λ for an electric line source, 1λ for a magnetic line source) multiple bounces of the surface wave component will have a significant effect for angles of incidence near grazing, and hence these have to be included in the total solution. The field contributions pertaining to the various rays shown in Figure 3 have been included in their respective domains of existence; in particular these contributions result from:

(i) direct fields.
(ii) reflected fields.
(iii) transmitted fields.
(iv) fields diffracted from both edges.
(v) surface waves excited by edge A, diffracted by edge B, and vice versa.
(vi) surface waves excited by edge A, reflected back by edge B, and finally diffracted by edge A, and vice versa.

It is gratifying to note that the field patterns depicted in Figures 4 and 5 for the electric and magnetic line sources that are based on our uniform geometrical theory of diffraction (UTD) ray solutions agree very well with the corresponding moment method solutions which are based on a totally different but formally exact procedure. It is noted that for angles of incidence close to broadside on the strip, the diffracted surface wave does not contribute much to the total

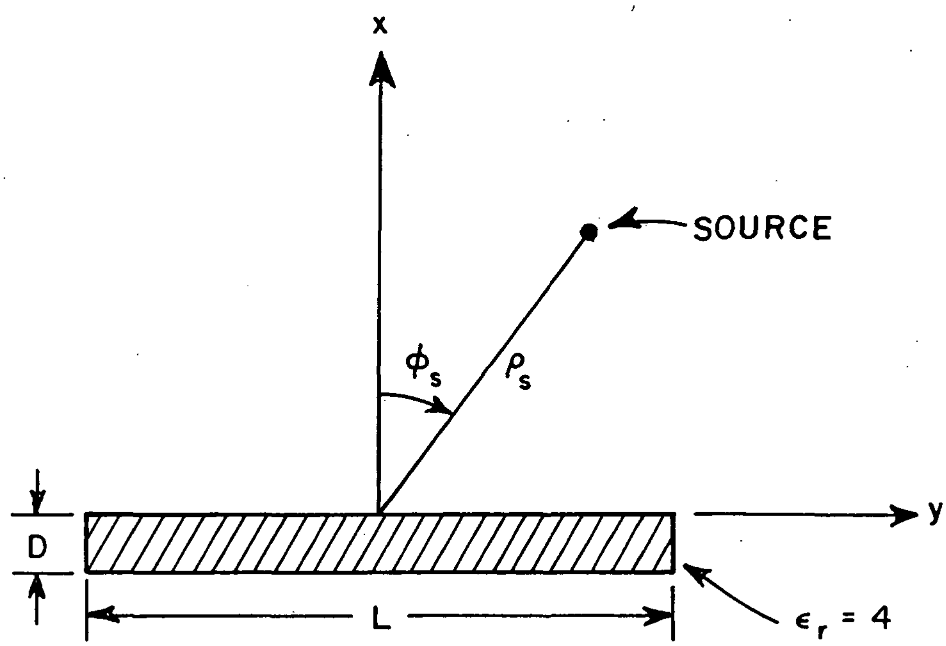

Figure 2. Geometry used for UTD-Moment Method comparison.

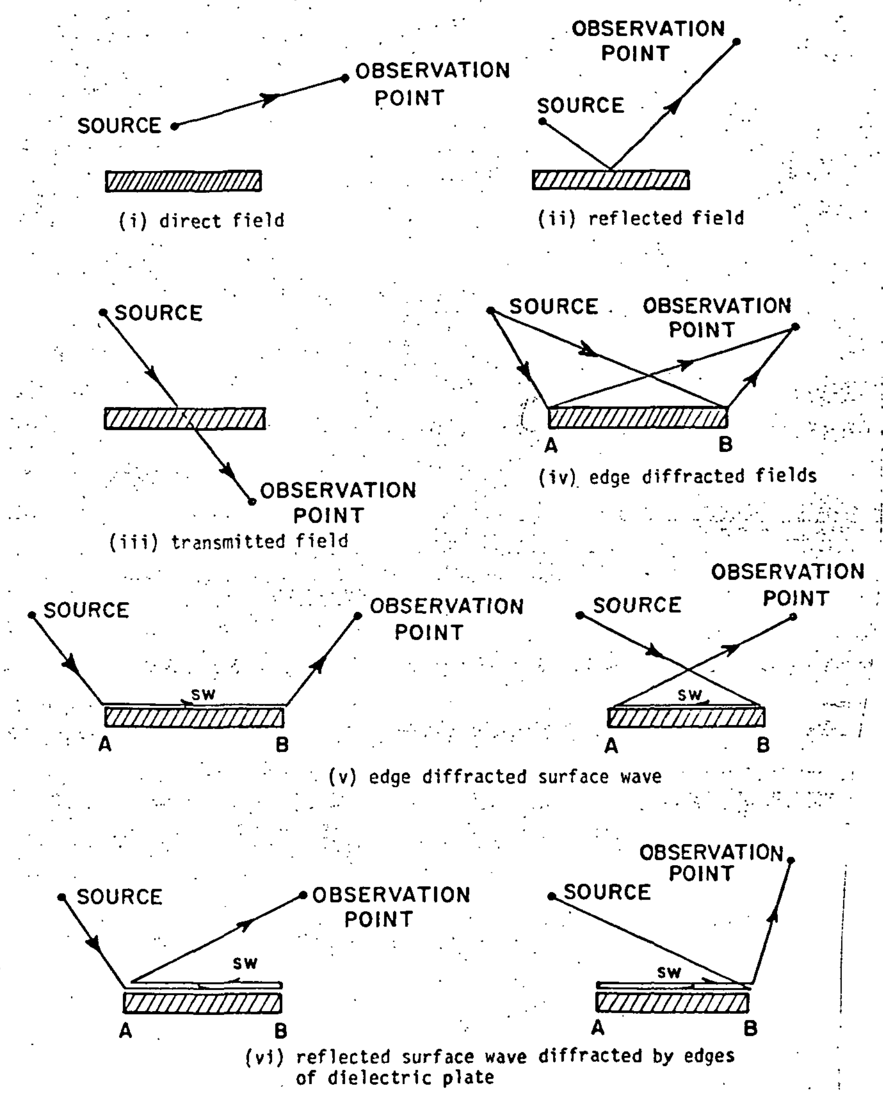

Figure 3. Various terms used in calculating the total UTD field.

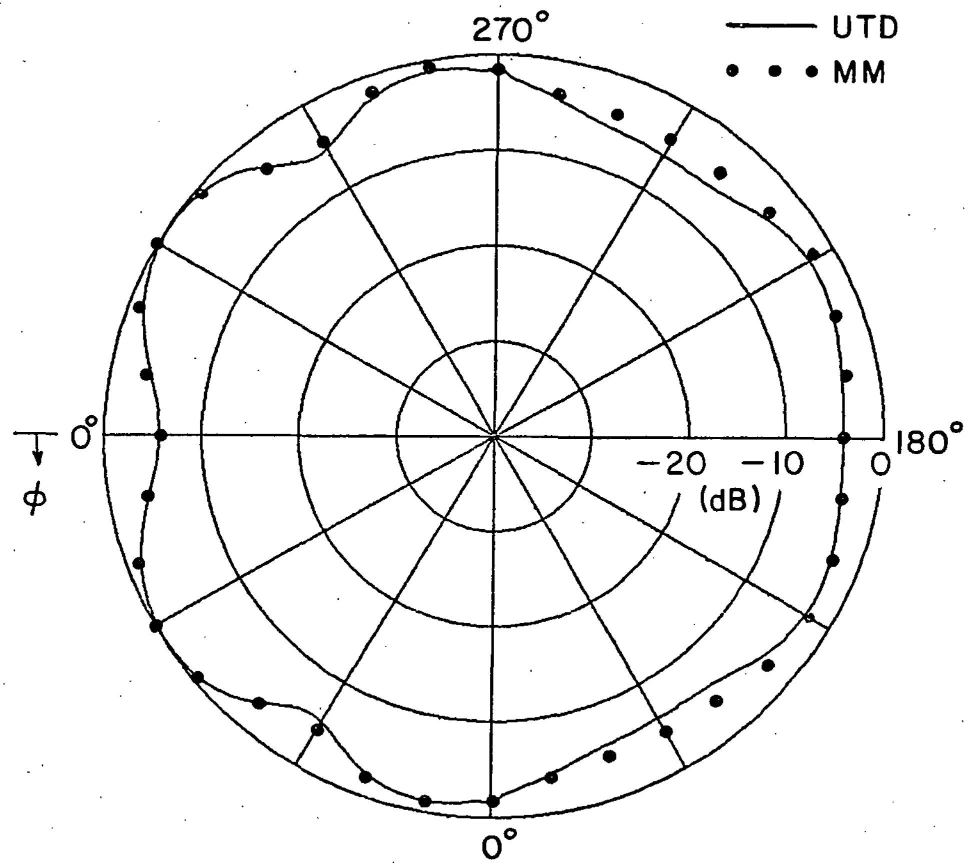

Figure 4a. UTD-MM comparison with electric line source, using geometry shown in Figure 2 with L=2.λ, D=0.05λ, ϕ_s=0.°, ρ_s=1.λ.

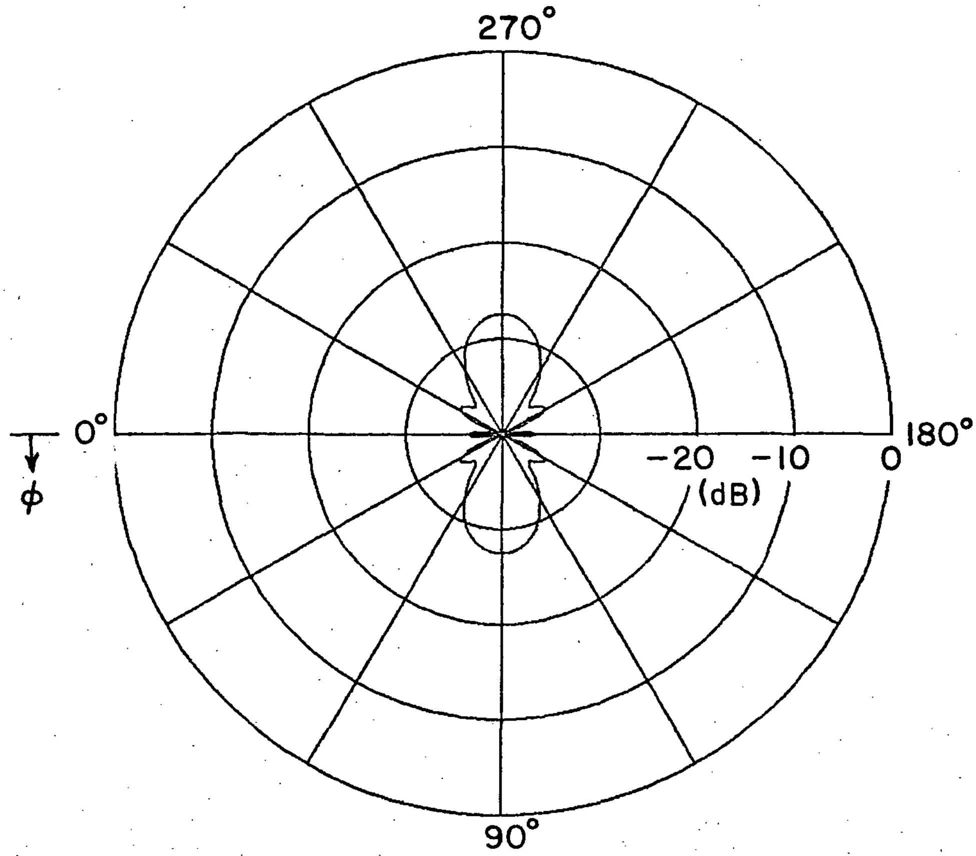

Figure 4b. Diffracted surface waves for an electric line source, using geometry shown in Figure 2 with L=2.λ, D=0.05λ, ϕ_S=0.°, ρ_S=1.λ.

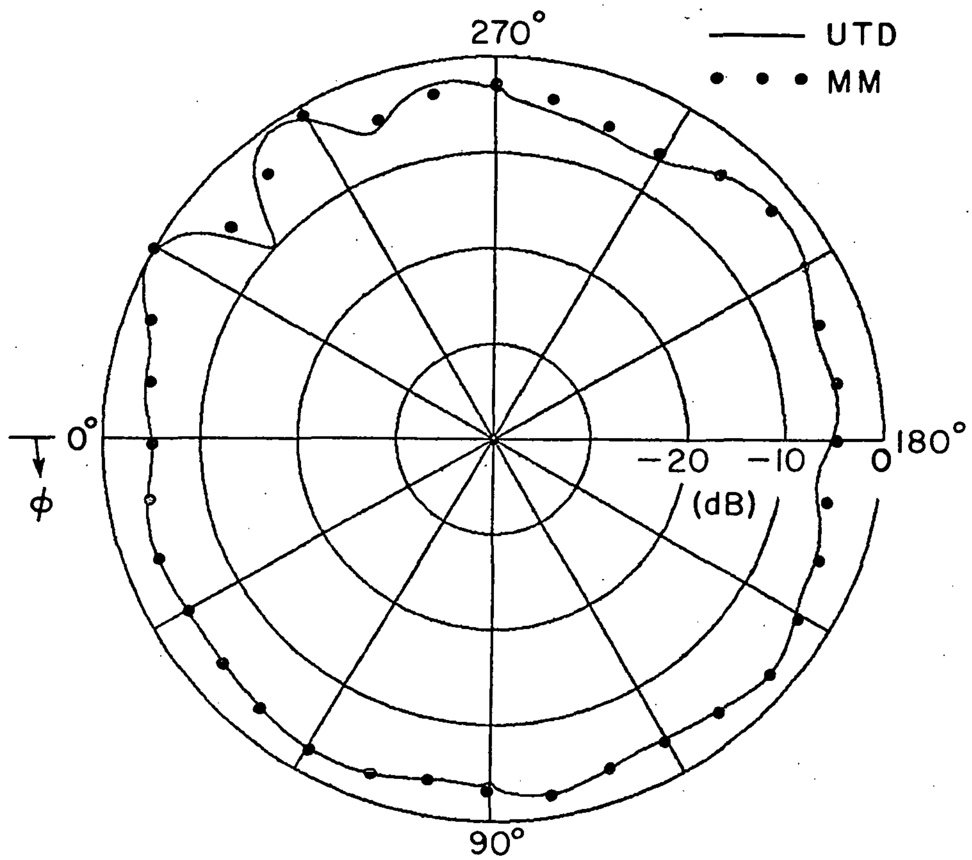

Figure 4c. UTD-MM comparison with electric line source, using geometry shown in Figure 2 with $L=2.\lambda$, $D=0.05\lambda$, $\rho_S=2.\lambda$, $\phi_S=40.°$.

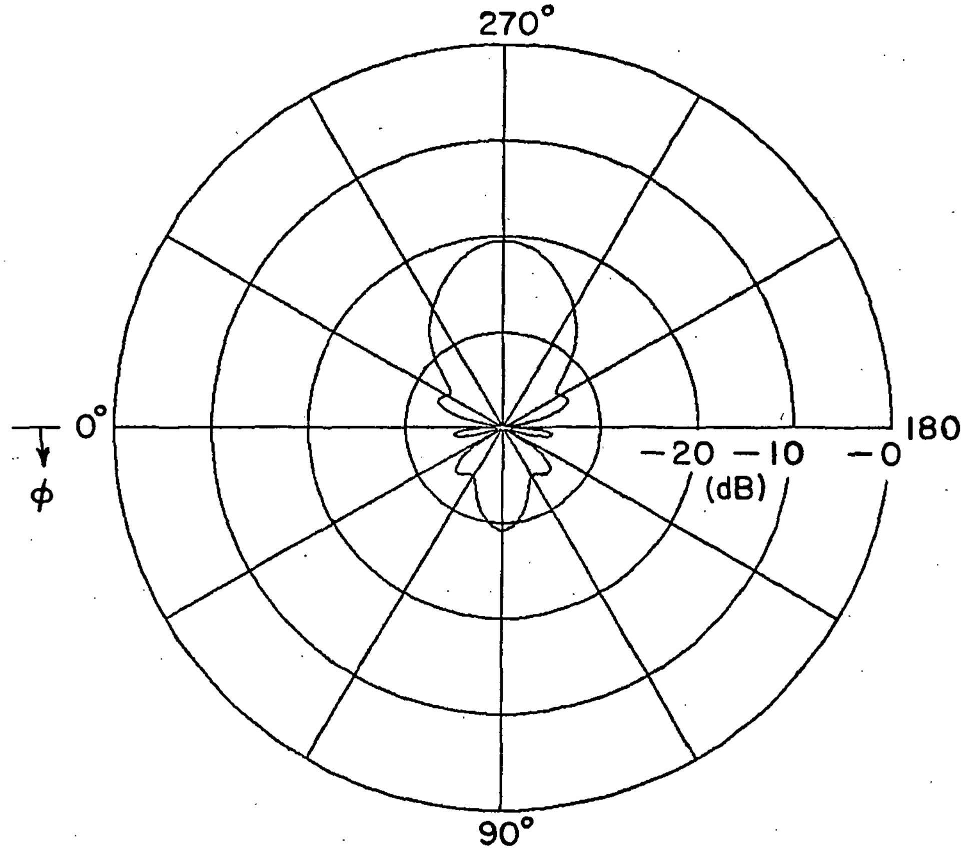

Figure 4d. Diffracted surface waves for an electric line source, using geometry shown in Figure 2 with $L=2.\lambda$, $D=0.05\lambda$, $\rho_S=2.\lambda$, $\phi_S=40.°$.

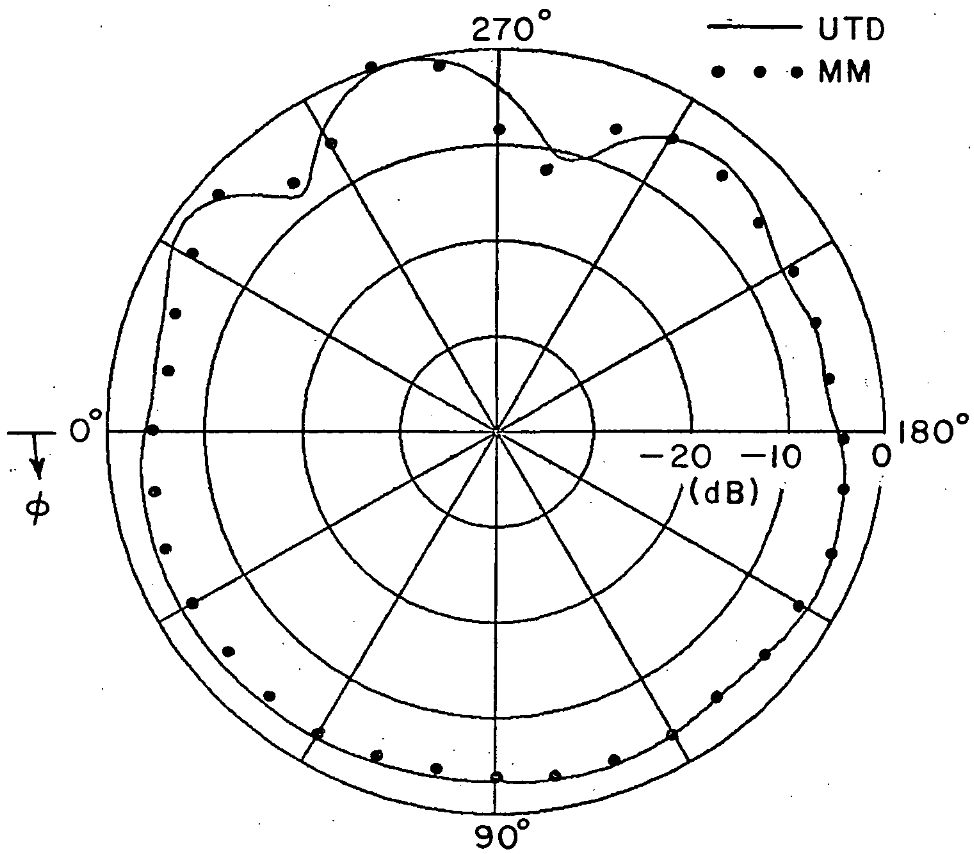

Figure 4e. UTD-MM comparison with electric line source, using geometry shown in Figure 2 with $L=2.\lambda$, $D=0.05\lambda$, $\phi_s=60.°$, $\rho_s=2.\lambda$.

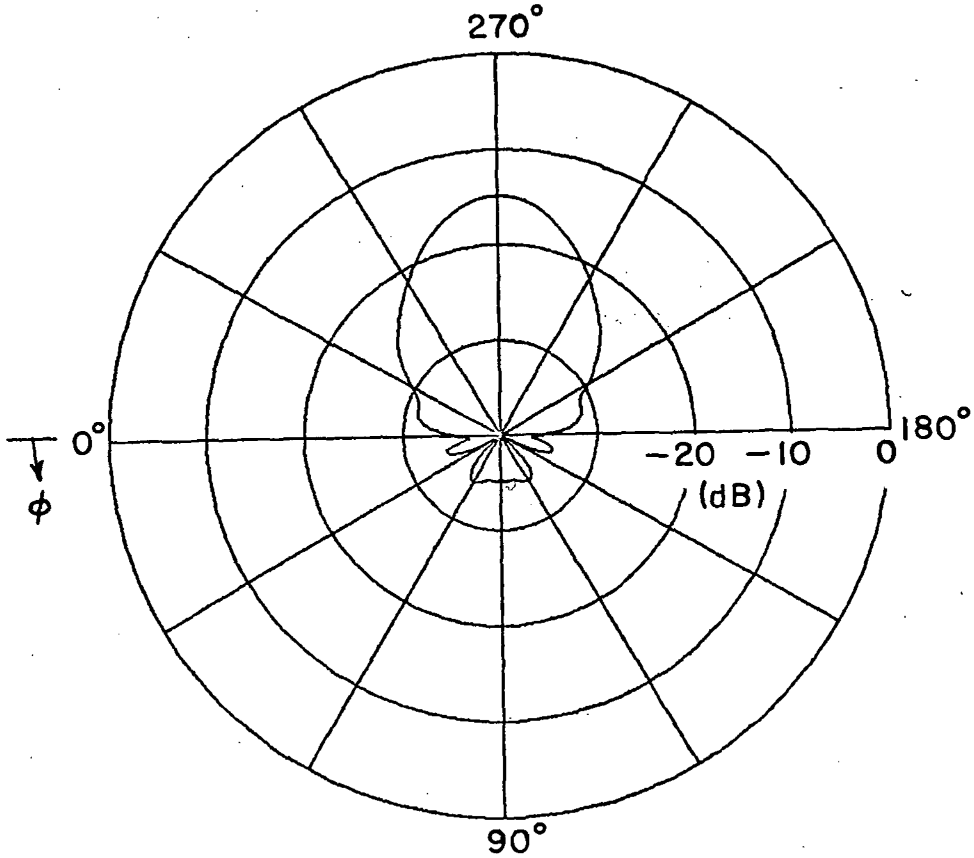

Figure 4f. Diffracted surface waves for an electric line source, using geometry shown in Figure 2 with $L=2.\lambda$, $D=0.05\lambda$, $\rho_S=2.\lambda$, $\phi_S=60.°$.

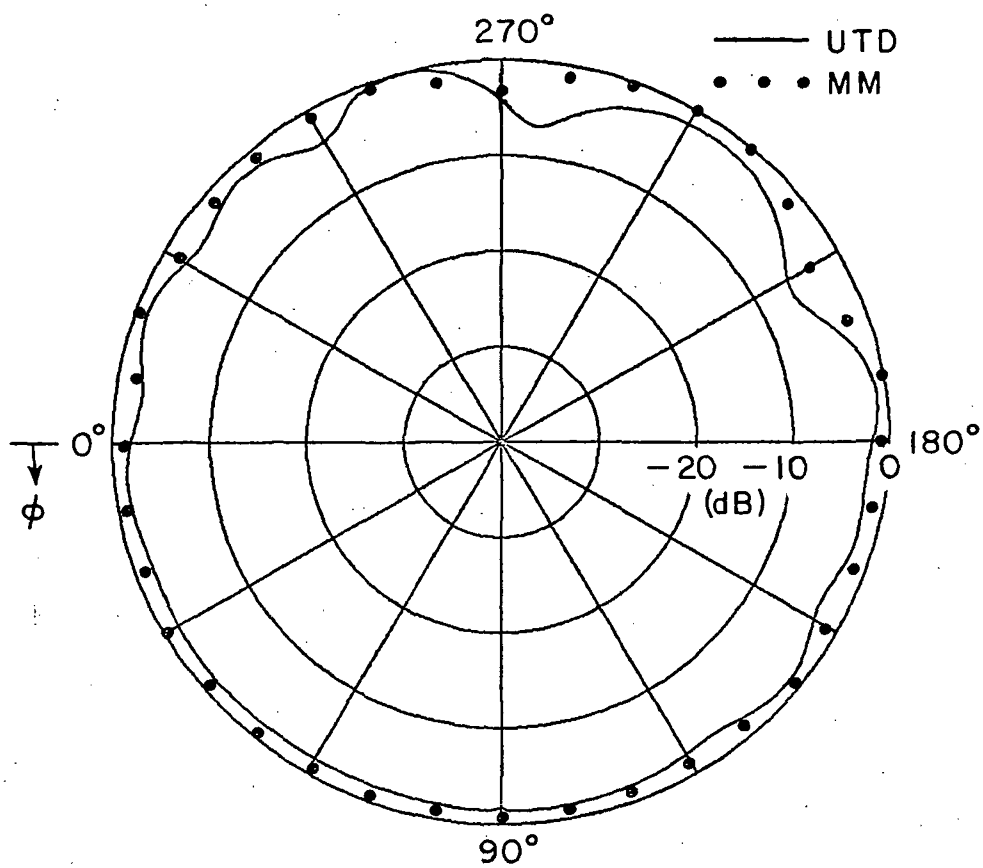

Figure 5a. UTD-MM comparison with magnetic line source, using geometry shown in Figure 2 with $L=1.\lambda$, $D=0.1\lambda$, $\rho_s=2.\lambda$, $\phi_s=60.°$.

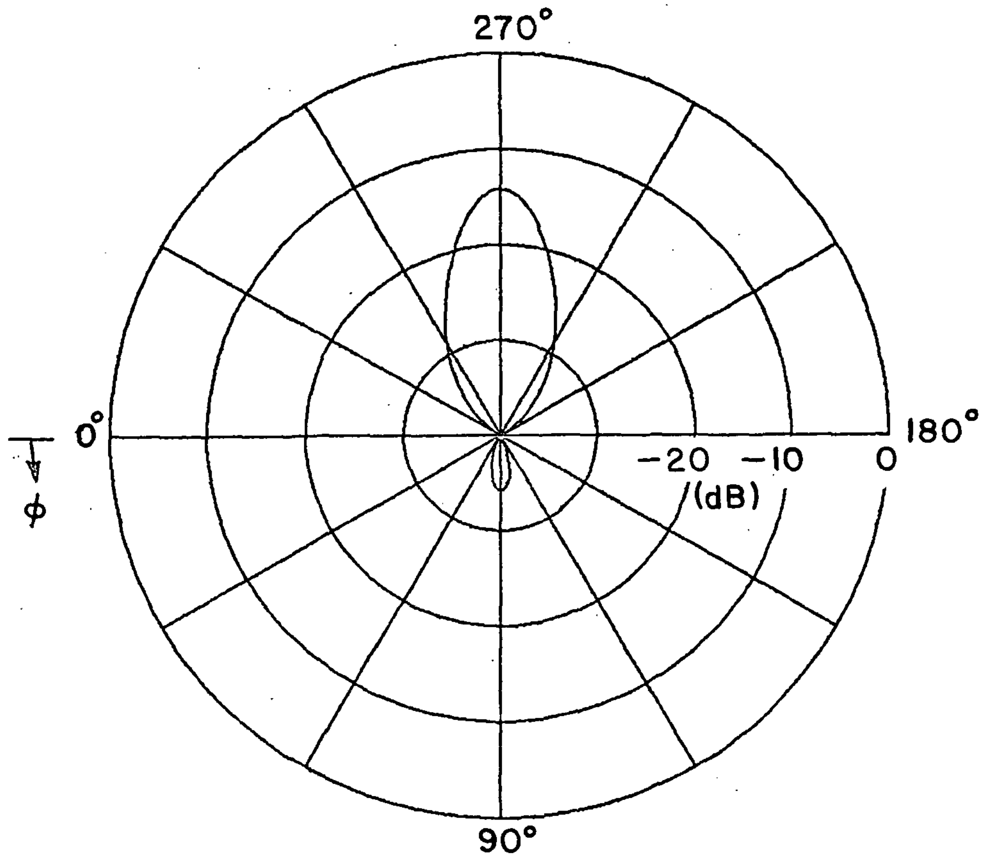

Figure 5b. Diffracted surface waves for an magnetic line source, using geometry shown in Figure 2 with $L=1.\lambda$, $D=0.1\lambda$, $\rho_S=2.\lambda$, $\phi_S=60.°$.

solution and thus, it can be neglected. On the other hand, for angles of incidence of 60° or larger from normal (broadside) incidence, the surface wave plays a significant role as expected, and the latter therefore, has to be included in the total solution.

The case of TE and TM leaky wave excitation of the thin dielectric half-plane is currently being analyzed. It is expected that this part of the study will be completed in the near future. In addition, the extension of the two-dimensional solutions to the three dimensional problem of plane, cylindrical, conical, and spherical wave excitation of a thin dielectric half plane is also being investigated as a part of the future work on this important problem.

The present UTD solution is in a form which suggests an ansatz for extending the thin dielectric half-plane diffraction coefficient to the case of a moderately thick dielectric half-plane. This extension and the extension to the three-dimensional case can be built up from the two-dimensional solutions.

IV. CONCLUSIONS

The high frequency simulation code used to compute the radiation patterns for private aircraft using a prolate spheroid to model the fuselage is about complete. This code will be ready for simulation verification during the next reporting period. The low frequency code development is just getting under way although we expect results which can be compared with experiment data within the next six months.

The theoretical development associated with the thin dielectric layer scattering is proceeding nicely. Presently, the surface wave aspects of the solution are being studied.

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