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FINAL SUMMARY REPORT  
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LOW SCAN ANGLE PERFORMANCE  
OF AIRBORNE FLUSH MOUNTED  
COMMUNICATION ANTENNAS

BY

DR. V. P. CABLE  
CALIFORNIA STATE UNIVERSITY, NORTHRIDGE  
JANUARY 1980



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## INTRODUCTION

World-wide communication links between aircraft and satellites place specific requirements on airborne antenna performance [1]. These requirements include antenna gains  $\approx 30\text{dB}$  and hemispherical scan coverage. The antennas used in present aircraft/satellite communication links are most often of the mechanically steerable reflector type and placement of the antenna has not been at issue since the antenna itself is located outside the main fuselage and must be covered by a rather large radome. The gain and scanning coverage of this overall antenna/fuselage system do not appear to have been studied either on an experimental or a theoretical basis. This does not seem unreasonable however, since gain and scanning range should not vary significantly from free space performance for these "raised" (or protruding) antenna systems.

Supersonic aircraft will no doubt be required to also participate in these satellite links in the near future and the primary impact of this will be on the antenna itself. Here, flush mounted electronically steerable arrays will be needed to satisfy the aerodynamic requirements of the fuselage. These flush arrays however, will generally be limited in practical gain and scan coverage [2]. Antenna performance in this case will be greatly affected by the fuselage structure.

Experimental studies of size and placement of these conformal arrays for optimum hemispherical coverage do not seem practical for either full sized aircraft or smaller scaled models. Hence, a theoretical model for simulating practical array configurations would be a valuable tool.

Significant theoretical work in airborne antenna pattern analysis has been made by Burnside, Marhefka and Hu [3,4,5]. The models used by Burnside, et. al. are based on high frequency GTD (Geometrical Theory of Diffraction) techniques developed by Kouyoumjian and Pathak [6,7]. Their analysis was confined to pattern calculations for verification of adequate coverage for specific antennas placed on the fuselage and wings. Other work based on these same GTD techniques has been done by Balanis, et. al. [8] for the MLS (Microwave Landing System) where simple slot antenna patterns were calculated in order to study coverage and polarization in the forward elevation plane.

DESCRIPTION OF WORK ACCOMPLISHED UNDER  
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The major effort of this study was to perform a literature search on electronically scanned conformal phased array antennas. The work of Borgiotti [9,10] and Borgiotti and Balzano [11,12] on periodic array structures and also the work of Shapira, Felsen and Hessel [13,14], Sureau and Hessel [15] and Knittel, Hessel and Oliner [16] on ray analysis and element patterns in periodic arrays were first studied in detail. Much of this work, of course, applies only to infinite or semi-infinite periodic arrays, planar or otherwise.

An investigation of the work done on finite array structures shows Steyskal's [17] work to be one of the only theoretical studies done in this area (circular apertures on cylinders) while Mailloux, et. al. [2,18,19] and Kummer et. al. [20,21] have done much of the experimental work on finite "limited scan" arrays. The results of these finite array studies are valuable to this work in the sense of being the best available theoretical and experimental stepping stones to other possible conformal array structures (presently in existence or innovative developments in the future).

A study of mutual coupling between array elements and its effect on element gains and active reflection coefficients was also performed by reviewing the works of Edelberg and Oliner [22] and Wasylkiwskyj and Kahn [23]. The latest techniques for computing mutual coupling between apertures on cylinders and cones appears to be that of Lee, et. al. [24,25,26,27,28] while some of the most original theoretical work on impedance conditions over cylindrical structures (which incidently, might prove to be last word in beam control for low scan angles) was done by Pathak [29] and Pathak and Kouyoumjian [30]. These overall asymptotic and GTD techniques from the Ohio State University and the University of Illinois are crucial to performing practical calculations on mutual effects over large cylindrical structures. The same can also be said concerning the ray optic and GTD techniques for computing field patterns associated with the entire antenna/fuselage structure.

In conclusion, it suffices to say that the time allowed for this study was basically just enough to gain a basic understanding of the latest techniques for investigating conformal phased array structures. A simple 3-D array scan model was developed however, using a hybrid of the techniques described by Stewart and Golden [31], Lee, et. al. [24] and Burnside [2] and a portion of a Master's Degree Project [32] was derived from this study. Hence, these results have been of significant educational value to this University and to its graduate program in antenna engineering.

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