# HEMISPHERICALLY SCANNED ARRAYS+

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## Introduction

Inertialess scanning techniques have been implemented in many different ways over the last decade, but the development of designs for airborne phase-scanned antennas has lagged behind that of ground systems largely because of the limitations of size, weight, volume, and cost.

The advent of satellite repeaters has opened a new field of communication technology: aircraft-to-satellite data links. To obtain maximum flexibility in operation of these links, it is desirable that aircraft have antennas that provide hemispherical coverage.

A basic problem in the implementation of satellite-to-aircraft communication systems arises because antennas that substantially protrude from the aerodynamic frame cannot be used on high-speed aircraft without causing a significant impairment in aircraft performance. Arrays conformal with the surface are an appropriate solution.

One approach to the design of the aircraft antenna is the use of a single aperture with the capability of full hemispherical scan coverage. This approach gives rise to a basic difficulty, that of antenna operation in regions near endfire. Although a significant amount of work has been performed on both planar and curved arrays for operation in regions about the broadside beam position, less attention has been devoted to the true endfire case and almost none to the transition region between broadside and endfire. It is the purpose of this paper to examine this particular problem. In the practical case of interest, the metal surface on which the array is assumed to be mounted is cylindrical, with a radius of curvature of 100 wavelengths.

In the study reported here, the interactions among radiating slots, surface wave structures and parasitic elements are considered in an effort to enhance coverage at the horizon and to obtain an array that can be scanned electronically from zenith to the horizon.

## Basic Geometrical Configuration

This paper describes studies of the interaction of radiating slots in conductors with various combinations of surface wave structures and parasitic elements to enhance radiation near the horizon. The study includes some analysis of patterns of slots and dielectric slabs on conducting groundplanes with curved ends. This structure simulates the effects of a cylindrical structure of large radius of curvature and yet retains the relative simplicity of a planar structure. The shape of the structure is shown in Figure 1. All patterns were computed and measured in the cut illustrated in that figure. Because of the curvature, the E-plane pattern of a vertical slot in the conductor without any surface wave structure suffers a fall-off at the horizon as illustrated in Figure 2. An analogous fall-off occurs for an axial slot in a cylinder, which is the more realistic operational situation. The H-plane pattern of a horizontal slot is illustrated in Figure 3. The problem being considered is to enhance the radiation at the horizon to obtain the desired hemispherical coverage.

## Slot With Dielectric Covers

To obtain some confidence in the surface-wave nature of the structures to be considered some patterns were calculated for various slot-dielectric combinations and were compared with measured patterns. For the E-plane patterns agreement between theory and experiment is quite satisfying. For the H-plane pattern the agreement is not as good. This difference in the H-plane case may be due to the presence of a greater reflection at the end of the dielectric that results because the thickness of the dielectric cover must be greater to support the TE surface wave than to support the TM surface wave. The theory used did not account for such reflections.

Various surface wave structures were tried experimentally. One structure that improved the E-plane radiation at the horizon without significant degradation elsewhere consisted of five layers of a glass tape material. Each layer was about 8 mills thick and two inches wide.

Both theory and experiment show that the surface wave structure does enhance radiation at the horizon in the E-plane, at the expense of some interference in the transition region. However, the effect on the H-plane patterns was not so promising. In order to broaden the H-plane pattern, various parasitic elements were studied. This study is described in the next section.

## Slot With Parasitic Element

In an effort to broaden the H-plane pattern of a slot radiator without affecting significantly

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the E-plane pattern, parasitic elements were investigated. The elements were metal rods and strips mounted over the slot and supported by a styrofoam block. Significant improvement in the coverage was obtained. At 70° from broadside the relative level is nearly the same as at broadside, as compared to about 14 dB down for the isolated slot.

A 2-inch strip of 1/4" wide aluminum tape over the slot instead of the rod gives a much smoother pattern with the same increase in coverage. The calculated pattern of a slot with a parasitic dipole above a groundplane is also shown for reference. The relative amplitudes and phases of the slot and dipole were determined empirically to fit the measured curve (Fig. 4).

## Element With Combined Surface Wave Structure and Parasitic Radiator

Patterns were measured of a slot with a surface wave structure to enhance E-plane radiation at the horizon plus a parasitic element to broaden the H-plane pattern. The configuration consisted of the half-height waveguide in the groundplane covered by 5 layers of 8 mil thick glass tape 2 inches wide and 25 inches long. A parasitic aluminum strip 1/8" wide was mounted 1/2 inch above the slot on a styrofoam block. The arrangement was sensitive to the length of the strip. As an example, an E-plane cut for a 2-inch length of aluminum tape shows that the radiation level at the horizon is enhanced, but 10 dB dips are introduced into the pattern. By decreasing the length of the metal strip it was possible to retain the enhanced radiation at the horizon in the E-plane and still obtain broadened coverage in the H-plane. This condition is shown in Figures 5 and 6 where the length of the aluminum tape has been reduced to 1-1/2 inch.

## E-Plane Patterns of Eight Element Linear Array

An investigation was made of the E-plane scanning characteristics of an eight element linear array of half-height waveguides in a groundplane with curved ends. Various surface wave structures were investigated to determine their effects on the scanning capability of the array, especially near the horizon (endfire). The radiators were fed through a corporate feed with magic tees at the junctions to provide isolation from element to element in the feed. Each feed line contained an attenuator, a phase shifter and a slide screw tuner so that the array could be arbitrarily excited and the elements could be matched individually.

Initially, the array was phased to give a broadside beam with no dielectric and then calculated phase shifter settings were used to scan the beam in 10° steps to endfire to examine the scanning characteristics without any surface wave structure added. A measured array pattern for a scan of 90° is shown in Figure 7. The patterns at scan angles of 60° and beyond show the effects of element pattern ripple and fall-off that results from the curvature of the surface. These effects tend to obscure the scanning effect, especially beyond 80°, so that the pattern at 80° appears very similar to that at 90 degrees. Only a slight shift of the nulls is detectable. It is in this region that the surface wave structure may aid in improving coverage.

One of the more promising configurations in examining the E-plane coverage of the isolated slot was the layered glass tape structure.

With the array covered by the glass tape the elements were adjusted to radiate with equal amplitude and in-phase along the horizon (90°). Figure 8 shows the pattern measured under this condition. It is evident that, while there is some distortion of the beam and still some fall-off at 90 degrees, the beam is narrower and the pattern level is several dB higher than that without the surface wave structure as shown in Figure 7.

## Conclusions and Recommendations

By using a combination of a surface wave structure and a parasitic radiator it has been possible to enhance E-plane radiation at the horizon and to broaden the H-plane pattern of a slot radiator in a conducting plane with curved extensions. The purpose of this modification is to improve the coverage obtainable when the radiator is used in an electronically scanned array.

The surface wave structure, which consisted of 5 layers of 8-mil thick glass tape, was also used with an 8-element linear array of slots oriented perpendicular to the array axis. This arrangement enhanced the radiation for a beam at the horizon (endfire), with little effect on the pattern when the beam was at the broadside region. The transition region needs to be more fully explored.

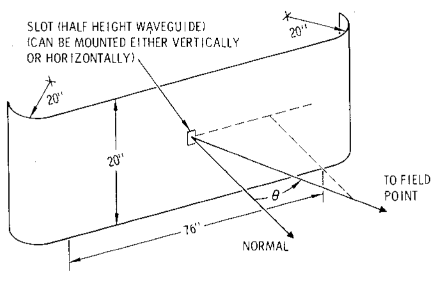


Figure 1. Experimental slot in groundplane with curved ends

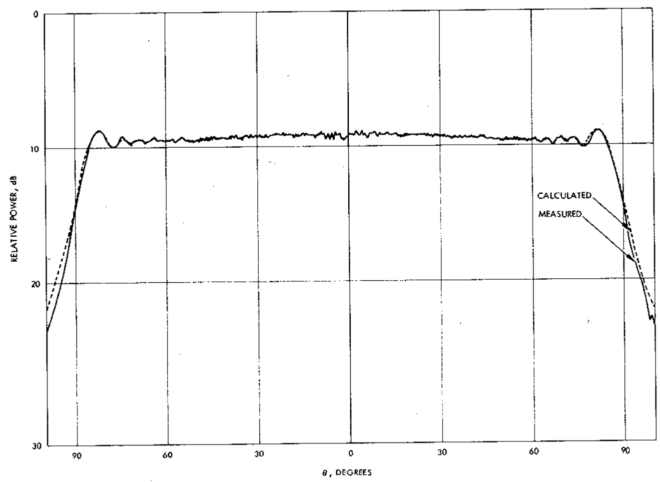


Figure 2. E-plane pattern of vertical slot in plane conductor with curved ends

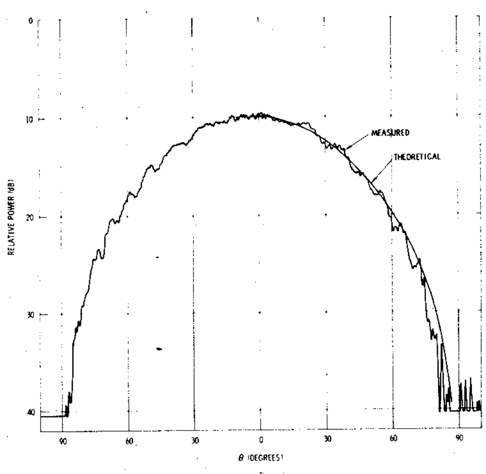


Figure 3. H-plane pattern of isolated slot

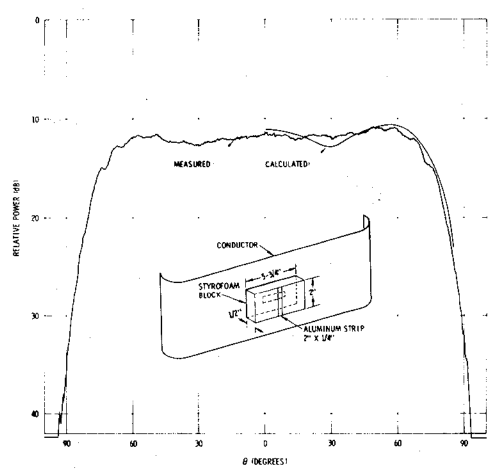


Figure 4. H-plane pattern of slot with single parasitic strip

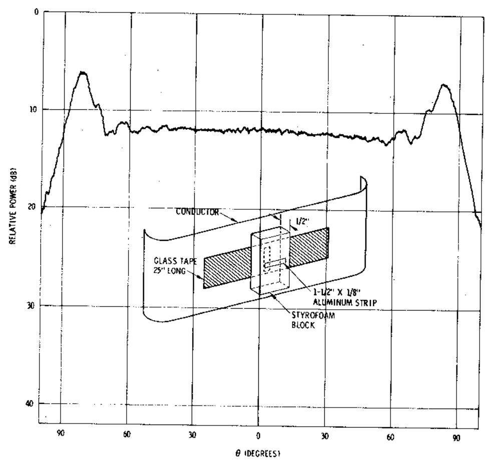


Figure 5. E-plane pattern of slot with surface wave structure and shortened parasitic strip

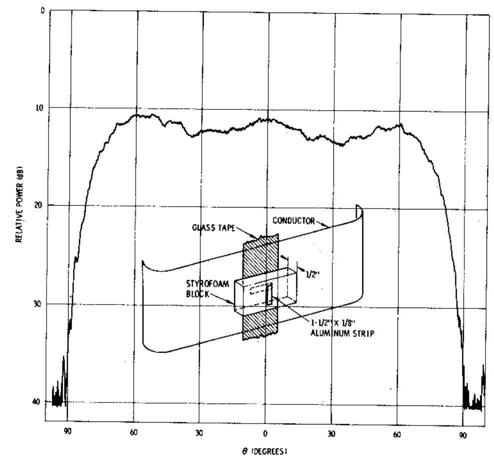


Figure 6. H-plane pattern for same arrangement as Figure 5

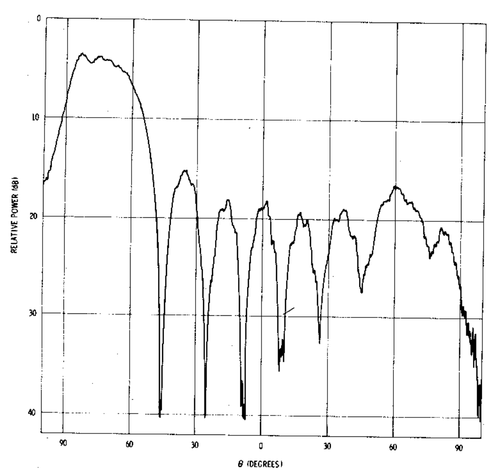


Figure 7. Pattern of 8-element linear array phased to radiate at horizon (no surface wave structure)

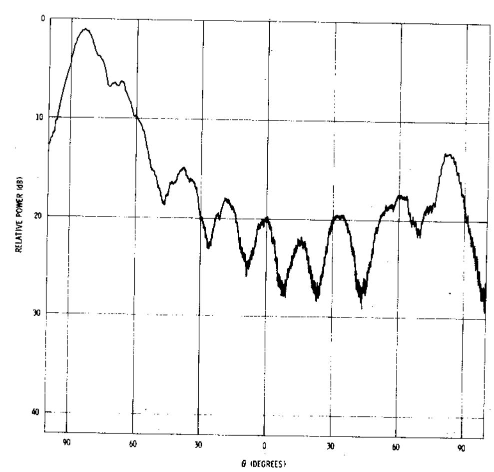


Figure 8. Endfire pattern of array with glass tape layers

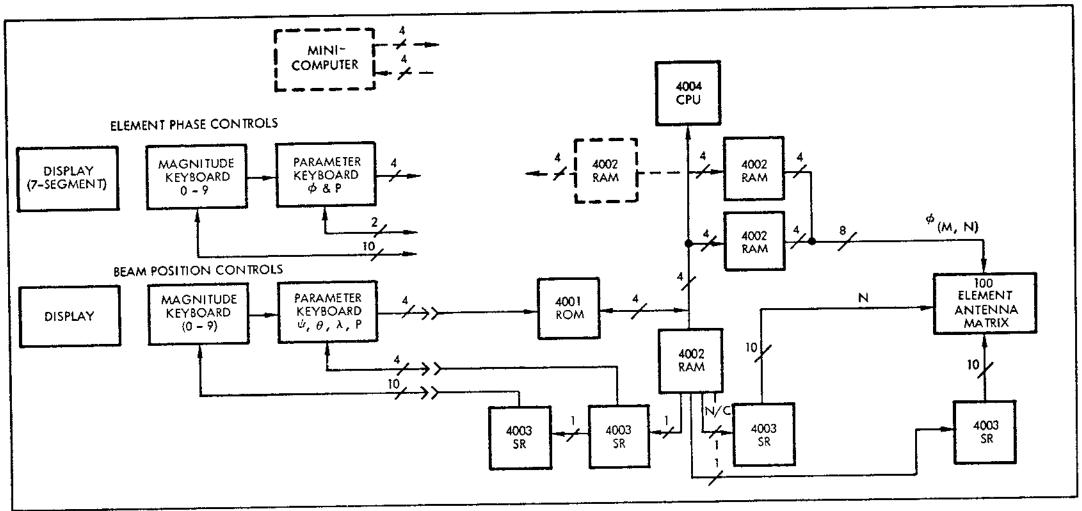


Figure 3 Microcomputer set Configuration for 10x10 Array Matrix

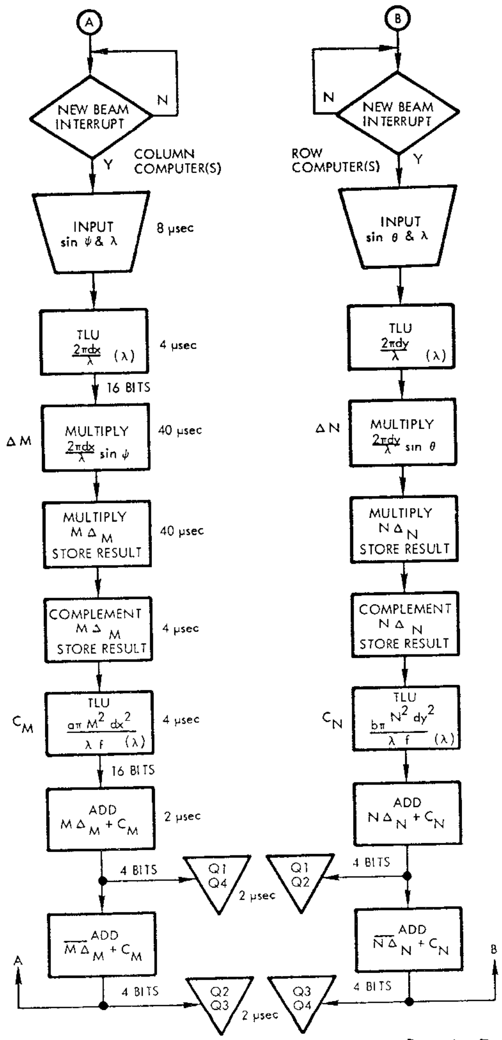


Figure 4 Microcomputer Flow Chart Row & Column Steering & Zoned Collimation

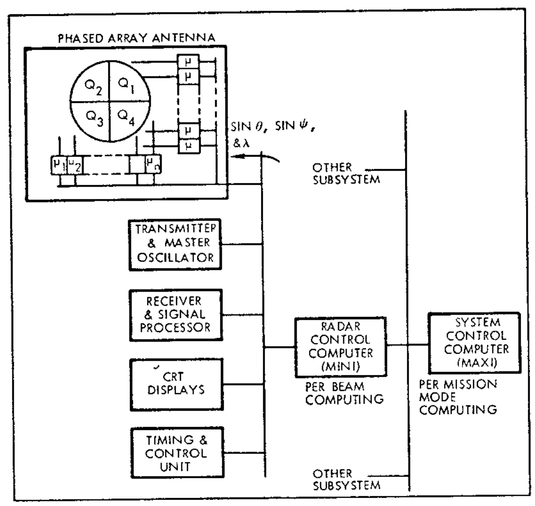


Figure 5 Integrated Microcomputer Phased Array Control