A-1766

FINAL TECHNICAL REPORT

SWITCHABLE-POLARIZATION STUDY ON AN/SPN-43A ANTENNA

EES/GIT Project A-1766

By

D. G. Bodnar and J. D. Adams

Prepared for

NAVAL ELECTRONICS SYSTEMS TEST AND EVALUATION DETACHMENT
(NESTED)
Patuxent River, Maryland 20670

Under

Contract N00421-75-M-5578

October 1975

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ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Atlanta, Georgia 30332

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FOREWORD

This Switchable Polarization Antenna Study was conducted under U.S. Navy Contract N00421-75-M-5578 by the Applied Engineering Laboratory of the Engineering Experiment Station (EES), Georgia Institute of Technology, Atlanta, Georgia 30332. The work was performed over the period 20 June through 31 October 1975. The authors would like to acknowledge the contributions of Mr. F. L. Cain and Dr. J. Lee Edwards of Georgia Tech to this program. Mr. John Guy and Mr. Preston Hopkins have directed these efforts for the Navy.

ABSTRACT

The objectives of the study undertaken under this contract were (1) to identify several candidate methods for switching between linear and circular polarization for the AS-2034/SPN-43A antenna, (2) to delineate the pros and cons of each of the candidate techniques, and (3) to recommend the best approach. Five general methods for achieving polarization switching were found to be applicable to the AS-2034/SPN-43A antenna. The approach recommended from this study is the circular waveguide approach. This approach is implemented by flaring the conventional rectangular S-band waveguide feeding the horn into a circular waveguide. A quarter-wave plate in a circular pipe is connected to the circular waveguide. One orientation of the quarter-wave plate produces horizontal polarization, while a 45° rotation of the plate produces circular polarization.

TABLE OF CONTENTS

LIST OF FIGURES

SECTION I

INTRODUCTION

The detection of a desired radar target in the presence of undesired radar backscatter such as weather clutter depends on some difference in the backscattered signals. Detection of aircraft targets in precipitation clutter can be substantially improved by using circular polarization instead of linear polarization, because of the well-known difference in the scattering properties of these two classes of scatterers when using circular polarization. Backscatter from precipitation has predominantly the opposite sense of circular polarization to that of the incident signal, and it is therefore rejected by the antenna; whereas a complex target such as an aircraft tends to depolarize the backscatter so that a significant component of the backscatter has the same sense polarization as that of the antenna and it is received [1].

Although the use of circular polarization enhances target detection in precipitation, it also tends to reduce the detection range in the absence of precipitation. Consequently, it is often desirable to make the polarization of an antenna switchable between linear and circular polarization. The need for switchable polarization on the antenna (designated the AS-2034/SPN-43A antenna) of the AN/SPN-43A radar has been established. The objectives of the study undertaken under this contract were (1) to identify several candidate methods for switching between linear and circular polarization for the AS-2034/SPN-43A antenna, (2) to delineate the pros and cons of each of the candidate techniques, and (3) to select the best approach. This report presents the findings on the above tasks.

SECTION II

USE OF CIRCULAR POLARIZATION TO REDUCE WEATHER CLUTTER

As indicated earlier, successful detection of a radar target in the presence of undesired backscatter, such as weather clutter, depends on differences in the backscattered signals [1]. Of course, the more dissimilar the target returns, the more effectively the undesired return can be discriminated against. The dissimilarity between echoes from precipitation and from complex targets such as aircraft may be used as a basis for discriminating one from the other.

A circularly polarized wave incident on a spherical scatterer is reflected as a circularly polarized wave with the opposite sense of rotation. (A circularly polarized wave is one in which the electric field vector rotates with constant amplitude about the axis of propagation at the radar frequency.) There are two types of circular polarization, distinguished by the direction of rotation of the electric vector as viewed by an observer looking in the direction of propagation. A wave having an electric field vector which rotates clockwise when viewed in the direction of propagation is said to be right-hand circularly polarized, while a wave whose electric vector appears to rotate counterclockwise is said to be left-hand circularly polarized. When a radar antenna radiates one sense of circularly polarized energy, this wave is reflected from a target such as a sphere or a plane sheet with the same rotation but the opposite direction of propagation so that the sense of polarization is reversed on reflection; that is, if a right-hand circularly polarized wave is transmitted, spherical raindrops reflect the energy as a left-hand circularly polarized wave, just as the mirror-reflected image of a right-hand machine screw appears to be left-hand. If the same circularly polarized antenna is used for both transmitting and receiving, the antenna is not responsive to the opposite sense of rotation and such backscattered energy will not reach the receiver. However, the backscatter from a complex target such as an aircraft will, in general, have components of both the incident and orthogonal polarizations. Energy incident on the aircraft may be returned after one "bounce," as from a plane sheet or a spherical surface; or, it might make two or more bounces between various portions of the target (similar to a corner reflector) before being returned to the radar. On each bounce the sense of polarization is reversed. Signals which make single reflections (or any odd number) will be returned with the opposite sense polarization and they will be rejected by the antenna, but those signals which make two reflections (or any even number) will be returned with the same sense polarization and they will be accepted.

A circularly polarized wave may be thought of as consisting of a horizontally polarized and a vertically polarized component with a 90° phase shift between the two. Thus, one method of generating circular polarization is to divide the transmitter power into two equal components, one horizontally polarized and the other vertically polarized, and to delay the phase of one of these components 90° relative to the other. The two components are radiated with equal amplitude. Both components are reflected equally by an ideal spherical raindrop. Upon reception, the phase-shifted component is again shifted by 90°, after which both components are added together. Since they are 180° out of phase and are of equal magnitude, they cancel and the raindrop echo is eliminated. An aircraft is not a symmetrical reflector; hence, the reflected components of polarization are unequal in amplitude and they are not completed cancelled at the radar antenna.

The ability of a circularly polarized antenna to reject rain echoes depends on the degree to which ideal circular polarization can be generated by a practical antenna and on the shape of the precipitation particles. The more spherical the particle, the more complete will be the cancellation of the backscatter. Cancellation ratios (cancellation ratio is the ratio of the received signal with circular polarization to the received signals with linear polarization) in excess of 30 dB have been achieved from dense rain clouds [2]. However, cancellation ratios of only 15 dB or less are obtained from non-spherical precipitation such as large wet snowflakes.

The radar cross section of aircraft targets is, in general, somewhat less with circularly polarized radiation than with linearly polarized radiation. The difference in the echo signal with circular and linear polarizations will depend upon the aspect from which the target is viewed. It is reported that, on the average, the cross-section with circular polarization is about 6 to 8 dB less than with linear polarization [3]. It is possible to enhance the radar cross-section for circular polarization with a beacon transponder or by installing a passive reflector which is responsive to circular polarization [4]. Since the echo signal obtained with circular polarization from aircraft targets is generally less than that obtained with linear polarization, the antenna should be designed so that either polarization may be selected by the radar operator, depending upon whether precipitation is present or not.

Cancellation of rain echoes through the use of circular polarization will be adversely affected by sea reflections [3,5]. It is possible for a portion of the transmitted energy to arrive at the target (and the raindrop) via a sea-reflected path as well as by the direct path. The illuminating field is a superposition of these two. In addition, the received signal may consist of energy reflected directly from the target and of reflected energy which is received after a sea bounce. The received energy is thus a superposition of two fields also. This superposition effect is especially important for antennas whose beams illuminate a smooth sea surface. The received echo signal is a composite of the direct and the reflected signals which can be relatively strong. Horizontally and vertically polarized signals are affected differently on reflection from the sea surface. As a result, a circularly polarized signal may be considerably depolarized when reflected from the sea surface. It follows that the cancellation ratio for precipitation clutter will be reduced when sea reflections are significant.

According to White [3], the use of circular polarization can improve the ratio of target signal to precipitation signal by 8 to 25 dB over that obtained with linear polarization, an improvement of 15 to 20 dB being representative of what can normally be expected under most conditions. An improvement of 8 dB represents that which might be expected with aspherical precipitation such as wet snowflakes. An improvement of 25 dB is possible when the raindrops are essentially spherical and when sea reflections are negligible.

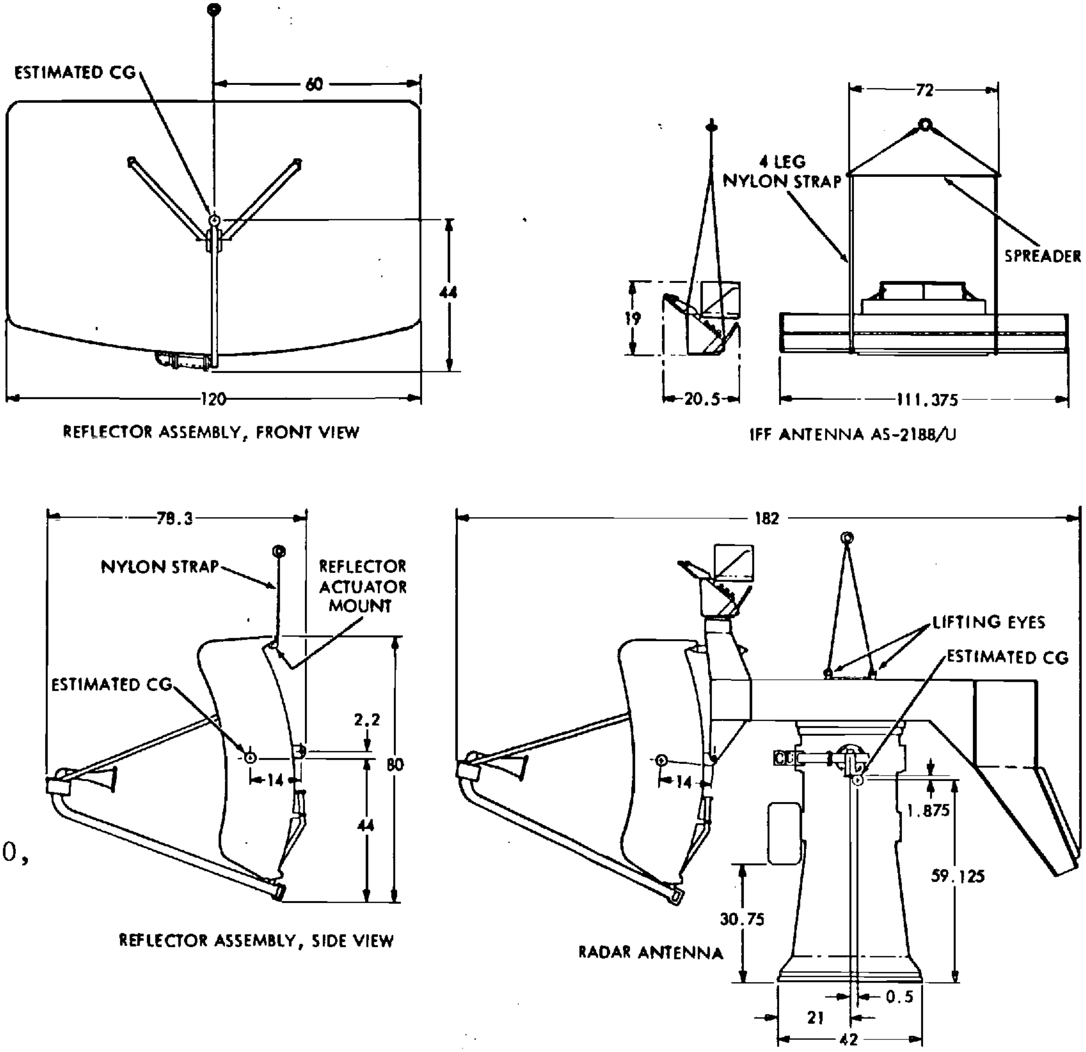
SECTION III

TECHNIQUES FOR ACHIEVING SWITCHABLE POLARIZATION

A. Introduction

The AS-2034/SPN-43A antenna is a center-fed shaped paraboloidal reflector antenna with a pyramidal waveguide horn feed, as shown in Figure 1. The solid reflecting surface of the antenna is approximately 120 inches wide by 72 inches high. A single waveguide run from the bottom of the reflector is connected to the pyramidal feed horn at the focal point of the reflector. The current feed horn is horizontally polarized and has a 5-inch high x 2.5-inch wide aperture. The flange around the aperture is 7.5 inches high x 4.5 inches wide. The pyramidal horn is connected by a 9-inch long straight waveguide section to a 90° H-plane bend which routes the waveguide toward the bottom of the reflector. The distance from the front face of the feed horn to the back surface of this 90° H-plane bend is 16.5 inches. A bracket which holds the feed in place extends an additional 3.5 inches behind the back side of the H-plane bend (see Figure 2). A tripod support maintains the feed in its proper location. This tripod support consists of two 2.0-inch diameter rods connected from the upper portion of the reflector surface to a mounting plate at the feed. The third leg of the tripod consists of the waveguide run from the bottom of the reflector surface. Any modification of the antenna must maintain the feed face at essentially the same location as that of the current feed, that is, at the focal point of the reflector. The simplest and most lightweight method for maintaining the feed location would be to continue utilizing the existing tripod feed support arrangement. This feed support philosophy has been adopted in this study.

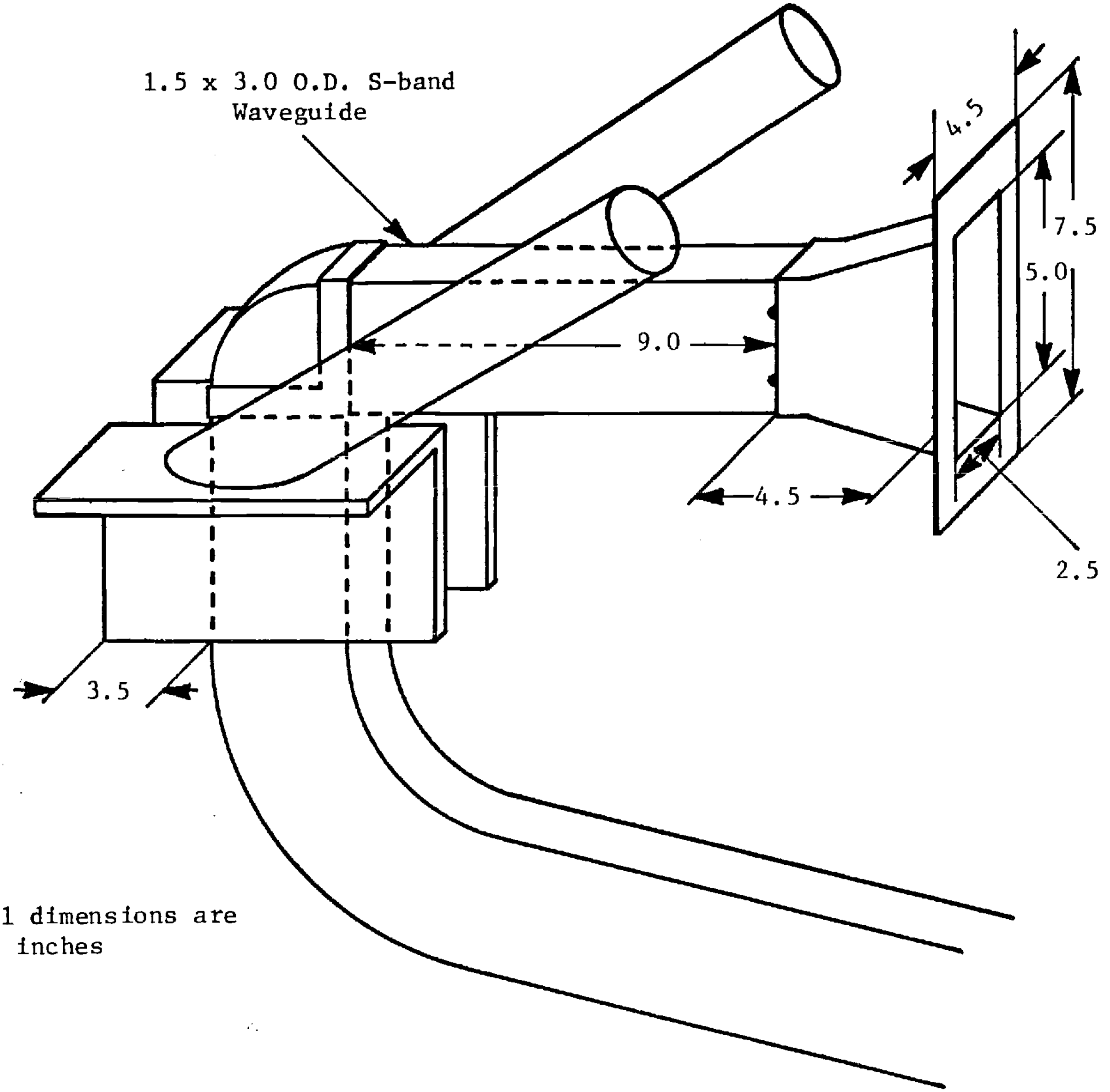
A number of schemes can be used for switching between linear and circular polarization. A number of approaches have been considered, and those



Note: All dimensions
are in inches

Reference: Technical
Manual for Radar
Set AN/SPN-43A,
NAVELEX 0967-436-3010,
15 February 1974

Figure 1. The AS-2034/SPN-43A antenna.



Note: All dimensions are
in inches

Figure 2. Current AS-2034/SPN-43A antenna feed horn.

most promising for the AS-2034/SPN-43A antenna have been investigated under this study. Five general methods for achieving polarization switching have been found applicable to this antenna. They are:

1. Circular waveguide approach,
2. Dual-mode horn approach,
3. Polarization grid approach,
4. Two-horn approach, and
5. Turnstile junction approach.

The basic concept for each of these approaches is explained below. Several variations on each approach are possible and the more important ones are discussed. The system parameters which affect the selection of a polarization switching method are presented in Table I. Each of these system parameters may affect each approach in different ways. These effects will be explained in the following sections.

Either of two basic philosophies could be used in making the desired modification. One approach places all of the polarization switching components at the feed, while the other approach places many of these components behind the reflector. The first approach makes for a compact design by keeping all the components in one location. However, it has a disadvantage of placing added weight at the feed point. The second approach places the added weight behind the reflector surface, thus changing the moment and stiffness characteristics of the feed and its support less severely. This second approach, however, may make it difficult to maintain phase matching if relatively long multiple waveguide runs are required.

B. Circular Waveguide Approach

This approach is implemented by flaring the conventional rectangular S-band waveguide feeding the horn into a circular waveguide. A polarizing

TABLE I

SYSTEM PARAMETERS WHICH AFFECT THE SELECTION OF SWITCHABLE POLARIZATION IMPLEMENTATION ON THE AS-2034/SPN-43A ANTENNA

Peak Power: 1 MW

Average Power: 1 kW

Pulse Width: 1 μsec

Frequency Range: 3.59 to 3.70 GHz

Minimum Range: 250 yards

Operating Ambient Temperature: -28° C to +65° C

Pressurization: 1.5 to 2.0 psig (dry air)

Allowable Increase in Length: 9 inches

Allowable Increase in Weight: 20 pounds

section of circular waveguide (e.g., a quarter wavelength plate) is connected to the circular waveguide. The polarizing section consists of a circular waveguide with a vane in it. The vane is so designed that a 90° differential phase shift is produced between the incident field components when the vane is oriented 45° to the incident E-field. No differential phase shift is produced when the vane is oriented perpendicular to the incident E-field. Horizontal polarization is obtained when the vane is oriented perpendicular to an incident horizontally polarized E-field. Circular polarization is obtained by mechanically rotating the polarizing section by 45°. The output of the polarizing section feeds a horn that illuminates the reflector. Choke grooves would be built into the ends of the polarization section to prevent arcing between the moving polarizer and the stationary waveguide and feed horn.

A number of implementations of the polarizing section are possible. Metal vanes, dielectric slabs, pins, and irises may all be used to produce the 90° polarization rotation. A more detailed study will have to be performed to determine the optimum design for producing the circular polarization. A number of factors must be considered in this design study, including bandwidth, power handling ability, size, and pattern ellipticity.

The new feed required for the circular waveguide approach consists of four distinct elements, namely, a new waveguide run from the reflector, a rectangular to circular waveguide adapter, a polarizer (a quarter wave plate section), and a feed horn (see Figure 3). A brief review of various designs for each of these units was undertaken to help in estimating sizes and consequently weights of the overall feed structure. Several designs appear feasible for the rectangular to circular waveguide adapter. This would be a relatively lightweight aluminum structure that does not rotate. Current estimates of the length of this section would be from 4 to 10 inches, depending

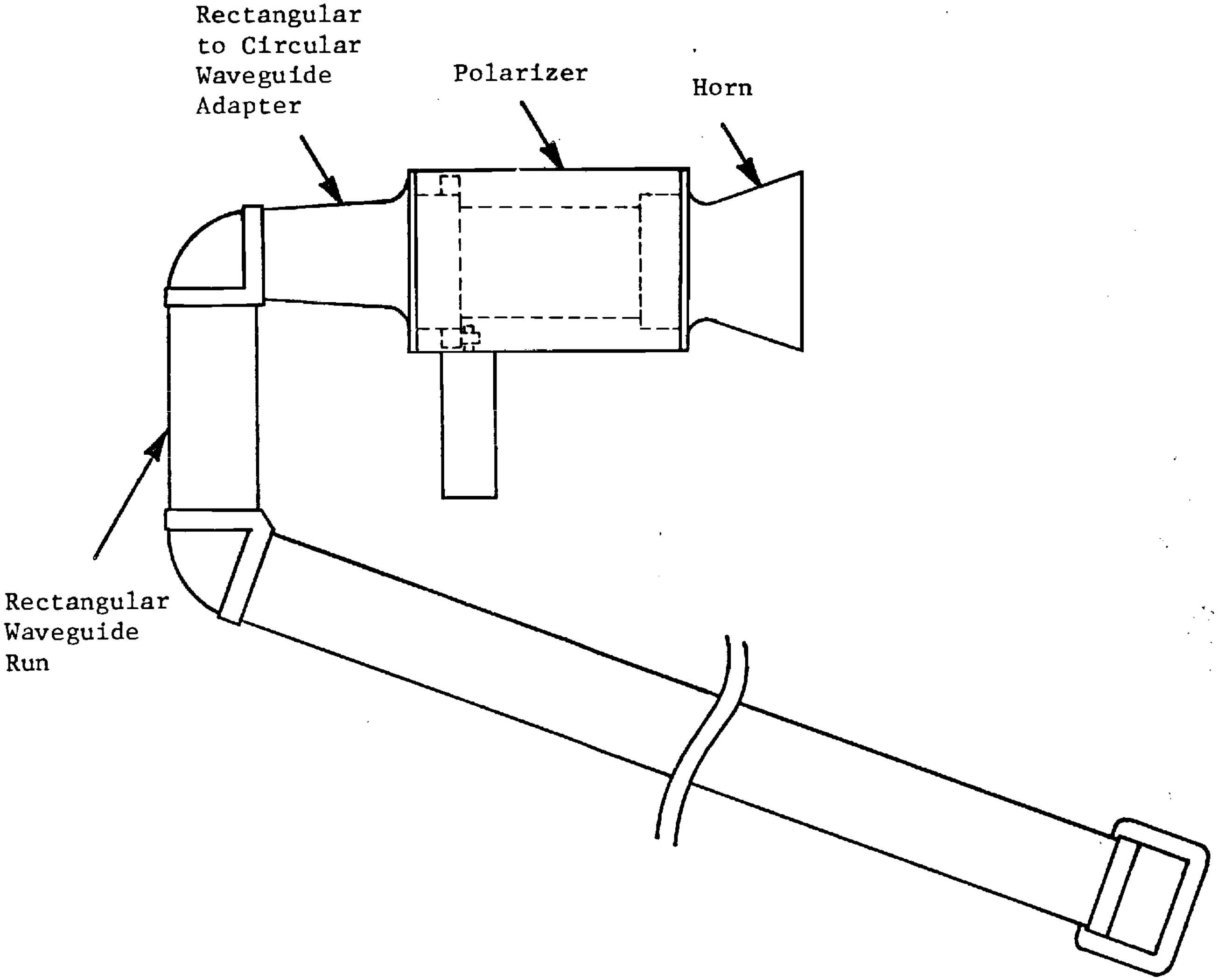


Figure 3. Microwave component layout for Circular Waveguide Approach.

on the design. The length of the adapter would probably be on the low end of this range of length variation since a relatively narrow band device is required (3 percent bandwidth). The longer length is needed only when a broadband structure is required.

Several designs were reviewed for the quarter wave plate section. Diameters of this section range anywhere from about 2.5 to 3.2 inches, although the length of the section may vary anywhere from about 6 to 11 inches. The longer lengths are usually associated with broadband devices and so it appears reasonable that the polarizer section for this application will be 6 to 8 inches in overall length.

Figure 3 shows a preliminary layout of the polarizer. The dotted lines inside the polarizer represent the circular waveguide section. The rectangular box extending out of the bottom of the polarizer represents a motor. This motor drives a gear train to rotate the polarizer. The motor rotates the polarizer 45° and thus switches between circular polarization and horizontal polarization. A metal housing covers the moving parts of the polarizer to protect them from the weather. The horn and rectangular-to-circular waveguide adapter are both rigidly attached to the non-rotating polarizer housing.

It appears that the present pyramidal horn on the SPN-43A antenna can be replaced by a similar elliptical horn which would mate to the circular cross section of the polarizer section.

Combined weight of the adapter, polarizer, motor, and horn is estimated at 12 pounds. Thus, the circular waveguide approach would increase the weight at the feed by approximately 10 pounds since the present horn and 9-inch waveguide run on the AS-2304/SPN-43A would be removed. The estimated length of the adapter and polarizer is 12 inches. This is about the same length as the current 9-inch waveguide run and 3.5 inch extension of the mounting bracket (see Figure 2). Our design will attach the tripod rods to the polarizer housing. Thus, a bracket extending beyond the waveguide will not be required.

It is possible to design the adapter, polarizer, and feed to operate over all of S-band if desired. However, the length of the adapter and polarizer would have tobe increased for broadband operation. The length could be as much as 21 inches as opposed to 12 inches for a narrow band design. Such a design would extend about 8.5 inches farther out than the present feed on the AS-2034/SPN-43A. It may be possible to reduce this length somewhat by careful design. With aluminum waveguide, the weight would increase only slightly due to the longer components.

C. Dual-Mode Horn Approach

A dual-mode coupler which permits vertically and horizontally polarized signals to be fed into a square waveguide forms the basis for this approach. A dual-mode coupler is attached to the horn feeding the reflector. Any sense of polarization may be radiated and received by adjusting the amplitude and phase of the two input arms to the dual mode coupler. Several methods can be envisioned for properly exciting the output ports to the dual mode coupler. One approach would utilize a short slot hybrid which produces equal amplitude signals 90° out of phase at its output arms. These two outputs would be connected to the two arms of the dual mode hybrid, thus producing circular polarization. By introducing a phase shifter in one of the arms, the 90° phase shift could be removed and equal amplitude, equal phase excitation applied to the dual mode horn. The horn would have to be oriented at 45° with respect to horizontal direction to obtain horizontal polarization with this excitation. Circular polarization would, of course, be obtained with this orientation when the ports were fed 90° out of phase. Alternately, two mechanical waveguide switches could be used to switch between two waveguide runs that differed in path lengths by 90°. The switches and waveguide runs would be used to replace the phase shifter.

Still another implementation involves the use of two 180° hybrids connected together with a phase shifter in one of the connecting arms. This combination permits variable power division to the two output ports by changing the setting of the phase shifter. One phase shifter setting would direct all power into the horizontal port of the dual-mode horn, thus producing horizontal polarization. A second setting would direct equal power to the two ports with 90° phase difference between them, thus producing circular polarization.

An advantage to the dual mode coupler approach is that it permits the polarization determining mechanism to be placed behind the reflector instead of at the feed horn, which is the case for the circular waveguide approach. The dual mode coupler and horn would be placed at the focal point of the reflector and two waveguide runs connected from the feed to the back of the reflector. The phasing circuitry would then be placed behind the reflector, thus keeping the majority of the weight near the center of gravity of the reflector system.

Figure 4 shows a layout of one method for implementing a dual mode horn approach. The transmitter/receiver is connected to the input. The short slot hybrid splits the input signal into two equal amplitude signals that are 90° out of phase. The polarizer in one state removes this 90° phase difference, thus producing equal amplitude and equal phase excitation of the dual mode coupler. Horizontal polarization is produced from this setting of the polarizer. Circular polarization is produced by changing the phase of the polarizer by 90°, thus producing 90° phase difference at the inputs to the dual mode coupler.

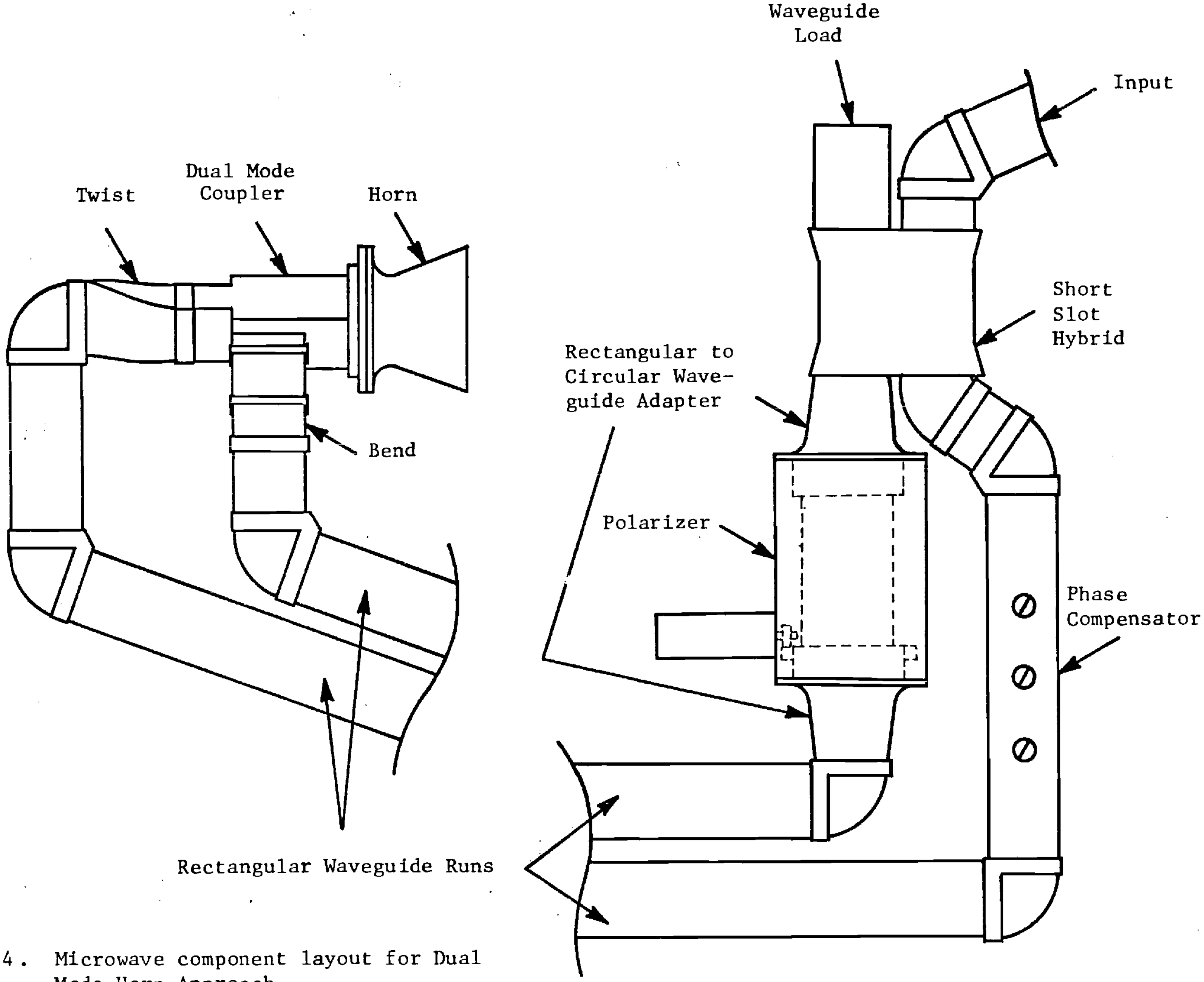


Figure 4. Microwave component layout for Dual Mode Horn Approach.

An analysis was performed to determine if a significant phase error would be produced due to differential heating of the waveguide runs from the hybrid to the dual mode horn. This differential heating might result, for example, from stack gas blowing on one waveguide more strongly than the other. This differential heating would produce a differential change in path length through the two waveguides, thus changing the relative phase of the excitation to the two ports of the dual mode coupler. If this differential heating were a problem, then metal straps could be welded between the two waveguides, increasing the heat flow between them and thus keeping the two waveguides at essentially the same temperature. Calculations indicate that a 25° F temperature difference between the two waveguides would produce a 2° phase difference in the two waveguides. Additional calculation indicated that the phase difference between the two runs should be held to approximately 2° in order to maintain a good (>20 dB) cancellation ratio from the antenna.

The major disadvantage of the dual mode horn approach is that it is more costly than the circular waveguide approach since it requires more components. In addition, if broadbanding is desired, there may be some problem in matching path lengths along the two waveguide runs to the feed, and the dual mode coupler is a narrow band device. Consequently, the cancellation ratio achievable from this approach may not be as good as that achievable with the circular waveguide approach. A major advantage of the dual mode horn approach is that it does not extend the length of the feed and so does not create a clearance problem with nearby obstacles.

D. Polarization Grid Approach

A polarizing grid may be placed across the output of the horn to produce circular polarization. A meander-line printed circuit board or a series of quarter-wave vanes could be used as the polarizing grid. Horizontal polarization would be achieved by mechanically rotating this grid to a position perpendicular to the incident E-field or completely away from the horn output. Rotating this grid 45° to the incident E-field would produce circular polarization.

1. Meander-Line Polarizer

The meander-line polarizer consists of several printed-circuit sheets with etched-copper meander lines. This device can convert linear polarization to circular polarization by the introduction of a 90° differential phase shift between two in-phase orthogonal linear components which are incident on the polarizer. For example, if a vertically polarized linear wave (E_v) is resolved into two equal components at $\pm 45°$ about E_v, one component passes through a structure which is equivalent to a broadband shunt-inductive filter while the other component passes through a broadband shunt-capacitive filter. These filter-like structures are designed to advance the phase of one component by 45° while the phase of the other component is retarded by 45°. The phase shifts through each filter-structure can be designed to have nearly equal slopes so that a differential phase shift of 90° can be achieved over significant bandwidths.

Typical construction of a meander-line polarizer would consist of four circuit boards printed with meander lines, and three sheets of foamed plastic as spacers [6]. Assuming a circuit board such as Teflon Fiberglas, most of the loss in this type of polarizer occurs in the meander line. The maximum power density which a meander-line polarizer can accommodate is limited by the heat which can be dissipated by the circuit boards. With one polarizer constructed with Teflon Fiberglas board, the boards turned yellow and the foam charred at a power density of about 100 W/in^2 [6]. However, current work indicates that this limit may be extended to near 200 W/in^2 through the use of other materials [7]. The average power density at the aperture of the feed horn of the AS-2034/SPN-43A is 80 W/in^2. This power density is sufficient to cause permanent damage to currently available meander-line polarizers, and so this approach is not recommended.

2. Metal Vane Polarizer

Like the meander-line polarizer, the metal vane polarizer is a transmission-type polarizer which derives its operation from the introduction of a differential phase shift between two orthogonal electric fields. Structure of the metal vane polarizer, along with design equations, is shown schematically in Figure 5. In operation, this structure is so oriented that the incident linearly polarized electric field is inclined at an angle of 45° to the plane of the metal plates. There are then equal field components, one parallel and one perpendicular to the plates. The component perpendicular to the plates will pass through the structure undisturbed, while the component parallel to the plates will "see" a waveguide structure and, hence, a phase shift relative to the perpendicular component. If the spacing and depth of the plates is adjusted correctly, the phase of the field parallel to the plates is advanced 90° with respect to the perpendicular component. Hence, this structure is commonly referred to as a quarter wave plate.

It is estimated that the weight of the metal vanes and rotating mechanism would be about 14 pounds. Addition of this type of polarizer and a rotation mechanism would probably cause significant degradation of the antenna pattern; therefore, this approach is not recommended for the AS-2034/SPN-43A.

E. Two Horn Approach

Two separate feeds could be used on the AN/SPN-43A antenna. One feed would be used for horizontal polarization while a second feed would be used to produce circular polarization. An electromechanical switch would be used

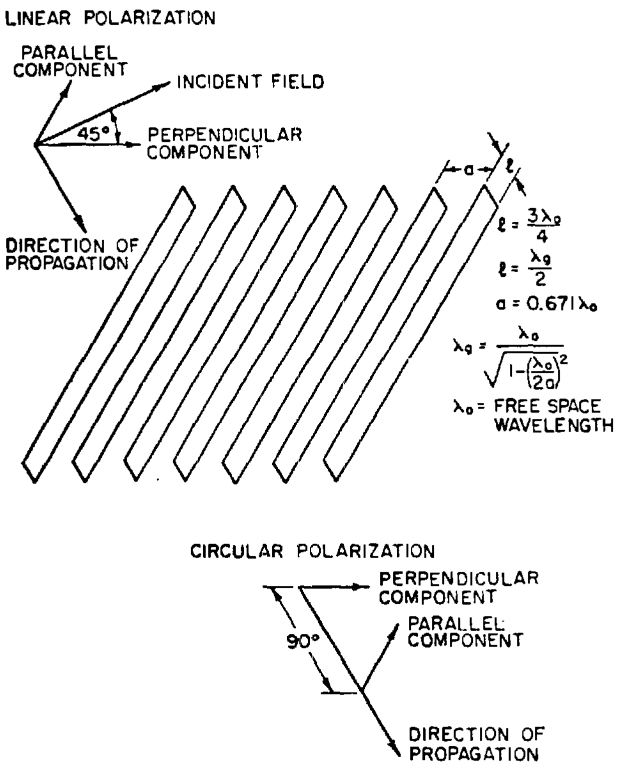


Figure 5. Parallel plate metal vane polarizer.

to switch between the two. If these two feeds were placed side by side in the horizontal plane, then a beam scan would occur in the horizontal plane when switching from horizontal to circular polarization. Calculations indicate that the beam would scan by approximately 2.1° or 1.4 beamwidths in switching between horizontal and circular polarization. This change in main-beam location could be measured and calibrated and removed from the CRT display. Alternately, the horns could be mounted one above the other in elevation if this azimuth beam scan is objectionable. The beam would then scan in elevation when switching from horizontal to circular polarization. This would be a more serious problem since the low elevation coverage of the antenna would be substantially degraded. Thus, although the two feed-horn approach is relatively simple to implement, it produces undesirable beam scan effects.

F. Turnstile Junction Approach

Another method of generating circular polarization is with the turnstile junction [8,9]. The turnstile is a waveguide device consisting of four coplanar, rectangular waveguide arms and one circular waveguide arm, orthogonal to the rectangular arms (Figure 6). The circular waveguide arm is capable of supporting energy received from any one of the four rectangular guides. When the junction is properly matched, power in rectangular arm 1 incident at the junction is divided as follows: one-half of the power enters circular arm 5 and one-quarter enters each of the adjacent rectangular arms 3 and 4. No power is coupled to arm 2 opposite the input. To generate circular polarization, short circuits are placed in the two adjacent sidearms 3 and 4. If the short circuit in one of the sidearms is placed five-eighths of a wavelength from the center of the junction and if the short circuit in the other sidearm is seven-eighths of a wavelength from center, the two signals reflected from the shorts will combine in phase in the circular arm and will be physically

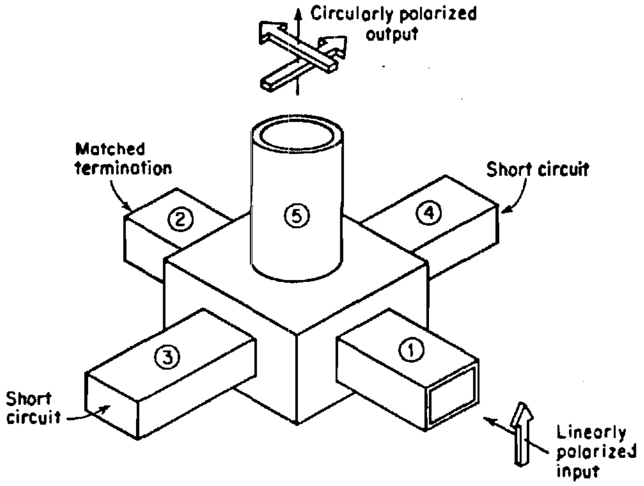


Figure 6. Turnstile junction used to obtain circular polarization.

orthogonal to, and 90° out of phase with, the signal coupled directly from the input arm to the circular arm. The two orthogonal components in the circular arm are equal in amplitude and 90° out of phase, satisfying the conditions for circular polarization. The fourth rectangular arm is terminated in a matched load. If the arms of the turnstile are terminated so that an input to arm 1 becomes a right-hand circularly polarized signal in arm 5, the turnstile will then couple a right-hand circularly polarized signal entering arm 5 into arm 1 and a left-hand circularly polarized signal entering arm 5 into the opposite arm 2.

The disadvantages of the turnstile junction are that it requires precise movement of shorts into the arms of the turnstile junction in order to achieve polarization switching. The turnstile junction approach would tend to be bulky, thus increasing aperture blockage and consequently sidelobe level. In addition, it may be difficult to construct high power moveable shorts that do not arc. This approach is bulkier, more complex, and so offers no advantages over the circular waveguide approach.

G. Ferrite Phase Shifter Considerations

Several of the schemes proposed require the use of a phase shifter in one of the microwave arms. Either a mechanical phase shifter or an electronic phase shifter can be used in this application. Several commercial companies were contacted regarding the possibilities of building a high power ferrite phase shifter at S-band for the AN/SPN-43A antenna application. Raytheon, Microwave Associates, Trak, and Electromagnetic Sciences were contacted in this regard. It was concluded from contacting these companies and from other information that an S-band reciprocal phase shifter capable of handling 500 kW to 1 mW peak power and 500-1000 watts average power is not feasible. It may, however, be possible to obtain a non-reciprocal phase shifter that is capable of handling such power levels. This type of phase shifter would have to be switched between transmit and receive. To maintain a 250 yard minimum detection range, the radar must be ready to receive approximately 1.5 μsec after transmission. Thus, the switching time of a non-reciprocal phase shifter must be 1.5 μsec, or less. The typical switching time which has been achieved with high power phase shifters is 10 μsec. With a 10 μsec switching time, the minimum range would become about 1670 yards.

The estimated loss of an S-band unit is 0.8 dB, while the weight would probably be 15 to 20 dB. A further consideration is the accuracy to which the desired phase shift can be maintained over the range of system parameters. Temperature would have an impact here. Although operating to +65° C would not be difficult, the phase shift would change with temperature. Closed-loop feedback techniques would be required to limit errors to a few degrees (∿5°) over the full temperature range. All of these considerations taken together make it seem unlikely that any approach requiring a ferrite phase shifter would be practical for the AN/SPN-43A antenna. In addition, a high switching rate from linear to circular polarization is not required, and so a mechanical phase shifting approach is satisfactory in this respect.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

The objectives of the study undertaken under this contract were (1) to identify several candidate methods for switching between linear and circular polarization for the AS-2034/SPN-43A antenna, (2) to delineate the pros and cons of each candidate technique, and (3) to select the best approach. Five general methods for obtaining polarization switching were found to be applicable for the AS-2034/SPN-43A antenna. They are:

1. Circular waveguide approach,
2. Dual mode horn approach,
3. Polarization grid approach,
4. Two-horn approach, and
5. Turnstile junction approach.

The circular waveguide approach and the dual mode horn approach were found most suitable for satisfying the operating conditions given in Table I without adversely affecting the pattern performance of the antenna. Both approaches use proven techniques for achieving polarization switching. An electromechanical phase switching mechanism is recommended over a ferrite phase shifter since ferrite phase shifters are not available in S-band to handle the power at the switching times required for the AS-2034/SPN-43A antenna.

The circular waveguide approach places all the polarization switching mechanisms at the feedpoint. Preliminary calculations indicate that this approach will not increase the weight of the feed by more than ten pounds, and that it can be packaged in the same length as the current feed. This approach requires the development of a quarter-wave plate type polarizer. Such devices have been built many times before and at various frequency ranges including S-band. It appears likely that this device can handle the 1 MW power of the AN/SPN-43A radar. However, no specific data on the maximum power handling capability of such a device at S-band are available. With this approach, high power tests of the polarizer would be necessary at an early state to verify that it can handle the required peak power.

The dual mode horn approach has the advantage that it allows some of the weight to be removed from the feed area and be placed behind the reflector surface. The polarization determining mechanism is placed behind the reflector surface, and a dual mode coupler and a feed horn are placed at the focal point. This approach has the advantage that the feed can be built in the same length as the existing feed on the AS-2034/SPN-43A antenna. It has the disadvantage that it requires two long waveguide runs to the feedpoint which must be equal in pathlength. Temperature differences or length differences in these runs could degrade the clutter suppression capability of this technique.

The findings of the present effort indicate that the most promising method for implementing polarization switching on the AS-2034/SPN-43A antenna is through the use of the circular waveguide approach. This technique is relatively simple and straightforward and uses the smallest number of components. It is recommended, however, that both the circular waveguide approach and the dual mode horn approach be pursued in parallel. In this manner, a higher probability of achieving a polarization switching scheme capable of handling the high peak power and satisfying all of the design objectives could be achieved.

SECTION V

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The objectives of the study undertaken under this contract were (1) to identify several candidate methods for switching between linear and circular polarization for the AS-2034/SPN-43A antenna, (2) to delineate the pros and cons of each of the candidate techniques, and (3) to recommend the best approach. Five general methods for achieving polarization switching were found to be applicable to the AS-2034/SPN-43A antenna. The approach recommended from this study is the circular waveguide approach. This approach is implemented by

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20. Abstract (continued) ·75·

flaring the conventional rectangular S-band waveguide feeding the horn into a circular waveguide. A quarter-wave plate in a circular pipe is connected to the circular waveguide. One orientation of the quarter-wave plate produces horizontal polarization, while a 45° rotation of the plate produces circular polarization.