COMPARATIVE TESTS OF VERTICALLY AND CIRCULARLY POLARIZED AIRPORT TRAFFIC CONTROL TRANSMITTING ANTENNAS

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SUMMARY

This report covers an investigation of the field patterns of two types of transmitting antennas. One type is a conventional "ground plane" antenna which radiates a vertically polarized wave, and the other type is a commercially developed antenna which radiates a circularly polarized wave

Two different types of aircraft receiving antennas were used in these tests. These are the horizontally polarized tail V antenna and the vertical antenna, both of which are mounted on CAA airplane NC-182, a Douglas C-47 aircraft.

All tests were made on a frequency of 118 7 megacycles, at an altitude of 1000 feet above ground

INTRODUCTION

Many articles pointing out the desirability of having similar polarization in a receiving antenna and a given transmitting antenna have appeared in the past 25 years At present, airport traffic control towers are equipped with vertically polarized transmitting antennas which work satisfactorily with vertically polarized receiving antennas. On the other hand, horizontally polarized receiving antennas are necessary for reception of horizontally polarized signals from navigation facilities

To eliminate the necessity of switching to a vertical antenna for the reception of control tower transmission, it is apparent that circular (or mixed) polarization of antennas for control towers is desirable The objectives of the tests described herein were (1) to obtain comparative data on the strength of the signal received by a vertically and by a horizontally polarized receiving antenna when a conventional vertically polarized transmitting antenna is used at a control tower, and (2) to obtain comparative data on the strength of signal received by a horizontally and by a vertically polarized receiving antenna when a new type of transmitting antenna, which radiates a circularly polarized wave, is used at a control tower

The circularly polarized transmitting antenna used in these tests was designed and built by the Federal Telecommunication Laboratories and loaned to the CAA for test It was designed to provide improved performance in airport control tower transmissions

DISCUSSION

The "ground plane" antenna consists of a vertical element at the base of which are four radially disposed horizontal elements. The lengths of the elements are adjusted until a proper match is obtained between the antenna and the 50-ohm coaxial transmission line.

The experimental antenna illustrated in Fig. 1 is an "electric-magnetic" dipole[1] consisting of two elements, a horizontal loop, and, at its center and perpendicular to the plane of the loop, a vertical radiator The r-f power is equally divided between the loop and the vertical radiator and the two currents are in phase This results in a radiated field which is circularly polarized and hence may be received by a horizontal, vertical, or diagonal antenna

In this particular design the horizontal loop is made in the form of an equilateral triangle with an impedance of approximately 1200 ohms at each corner The three corners of the loop are connected to a common point through a half-wave section of RG 8/U transmission line. The use of a half-wave line for this purpose does not alter the impedance of the loop at its corners, but the resulting impedance at the junction of the three half-wave lines becomes 400 ohms The vertical radiator, whose impedance is also 400 ohms, is tied to the junction point of the half-wave sections connected to the three corners of the loop The net impedance at the junction of the loop and vertical radiator is therefore approximately 200 ohms This is in turn transformed to 50 ohms by means of a quarter-wave transformer

[1] A G Kandoian, "Three New Antenna Types and Their Applications", Proceedings of IRE, Vol 34, No. 2, February, 1946.

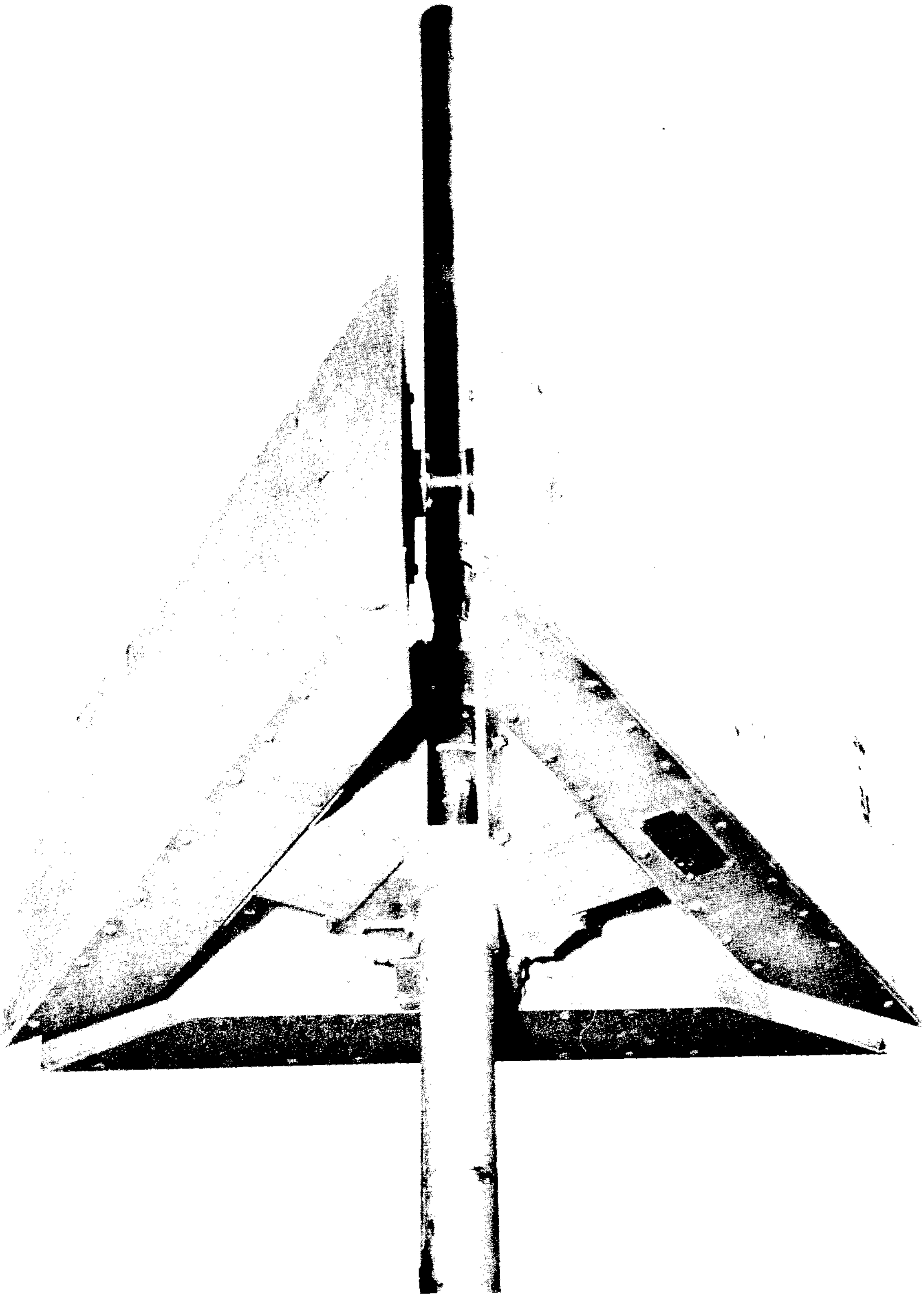

Fig. 1 Circularly Polarized Antenna

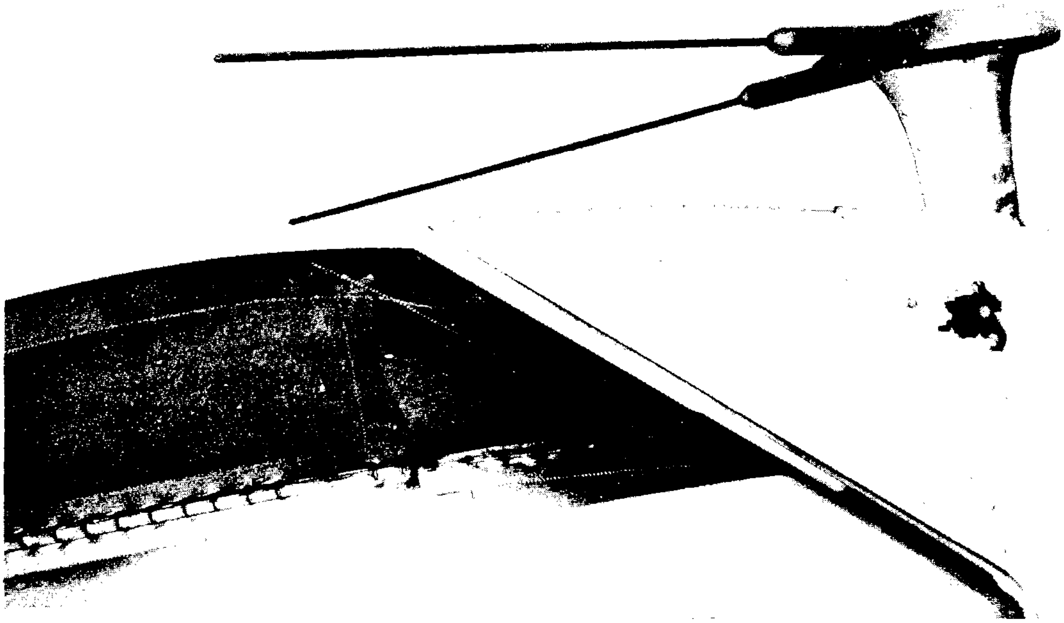

Fig. 2 Horizontally Polarized Tail V Receiving Antenna

The two transmitting antennas were mounted on top of the Indianapolis control tower and alternately supplied with r-f energy from a type TUI transmitter rated at 40-watts output. Whenever transmitting antennas were changed, the antenna coupling was adjusted so that the plate input power to the final amplifier was the same in either case. The transmitter was modulated 80 percent with 1000-cycle audio voltage.

Two different types of aircraft receiving antennas were used. One of these was a vertical antenna mounted on top of the fuselage about 15 feet forward of the vertical stabilizer. The other antenna, Fig. 2, was a horizontal broadband V mounted at the top of the vertical stabilizer.

The receiver used in these tests was a modified ARC-5 superheterodyne, manufactured by the Aircraft Radio Corporation, with the AVC circuit rendered inoperative. The volume control was removed from the receiver and replaced by an external decade resistance box so that accurate calibration of the receiver could be made. The output of the receiver was rectified by a small copper oxide rectifier, the d-c output of which was connected to an Esterline-Angus five-milliampere recorder. The calibration curves showed milliamperes deflection of the recorder meter versus microvolts input to the antenna circuit of the receiver for various settings of the decade box sensitivity control.

FLIGHT TESTS

Flight tests were divided into three types which were made at an altitude of 1000 feet above the ground as follows: (1) long radial flights between points 70 miles south and 70 miles north of the Indianapolis control tower; (2) short radial flights between points ten miles south and ten miles north of the Indianapolis control tower; and (3) circling flights at a radius of ten miles from the control tower.

During the long radial flights, the sensitivity of the receiver was adjusted, as necessary, to keep the recorder meter on scale. The results of the long radial flights are given in graphic form in Figs. 3 and 4. When the vertical transmitting antenna was used in conjunction with the vertical receiving antenna, a usable signal was available approximately 65 miles south of the control tower. Under identical transmitting conditions, when the tail V receiving antenna was substituted for the vertical receiving antenna, the distance at which a comparable signal was received was reduced to about 30 miles.

When the circularly polarized transmitting

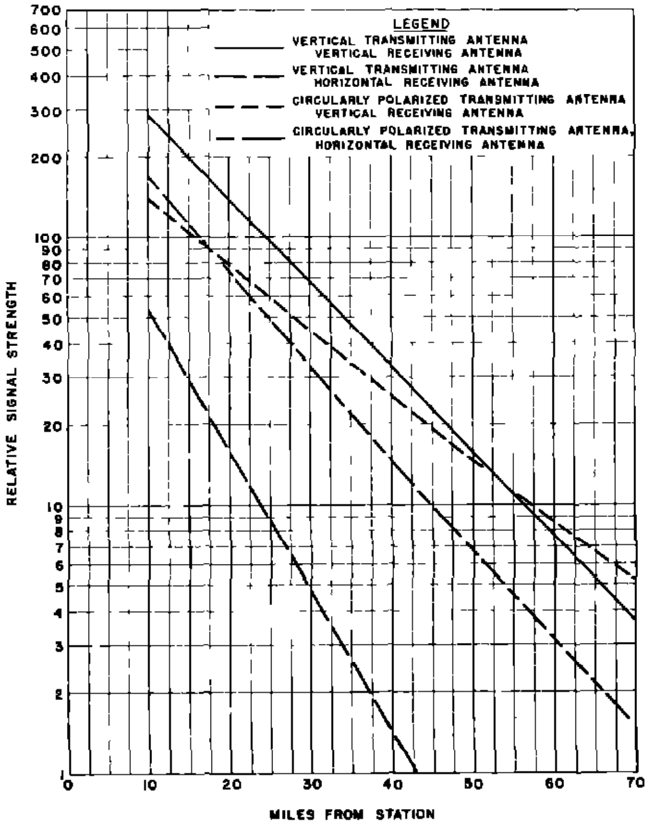

Fig. 3 Relative Signal Strength at Various Distances South of the Transmitting Station Using Different Combinations of Transmitting and Receiving Antennas

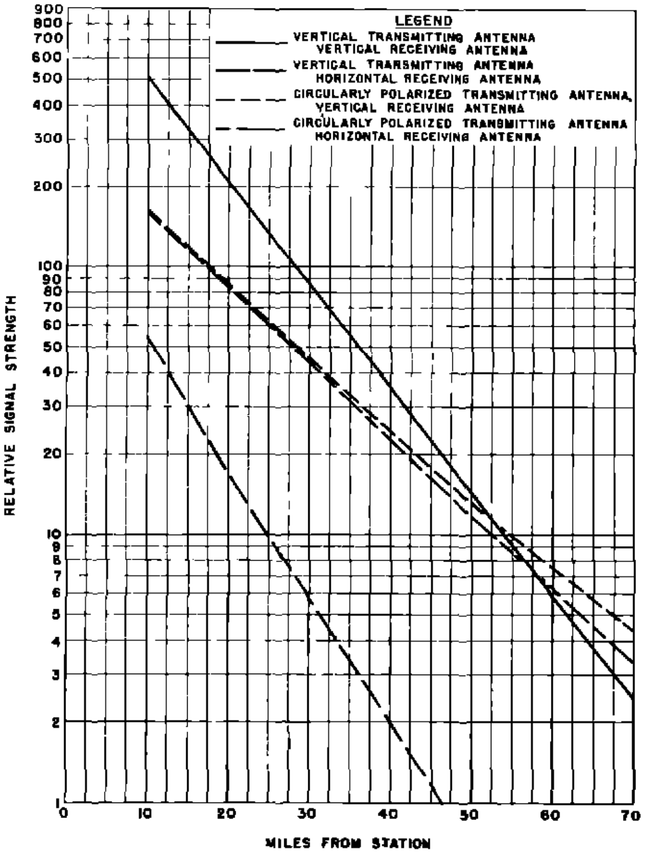

Fig 4 Relative Signal Strength at Various Distances North of the Transmitting Station Using Different Combinations of Transmitting and Receiving Antennas

antenna was used in conjunction with the vertical receiving antenna, the signal was received to about 60 miles. Substituting the tail V for the vertical receiving antenna reduced the useful range of the signal to 55 miles.

During the short radial flights, the receiver was adjusted to a low value of sensitivity and not changed until each of the individual flights was completed. Recordings of these flights made while using the circularly polarized transmitting antenna and the vertically and horizontally polarized receiving antennas are shown in Fig 5. Polar diagrams, based on recordings made while circling the control tower at a distance of ten miles, are shown in Figs 6, 7, 8, and 9 All are plotted to the same scale.

Because of the directional characteristics of the tail V antenna, the signal strength recorded is not as great as it would have been on a radial flight In order to make a comparison of the two transmitting antennas, the values of signal strength recorded while using the tail V antenna were multiplied by a factor of three to change them to the values that would have been expected during radial flights. It was assumed that the field pattern of the vertical receiving antenna was essentially circular and would produce the same signal strength, at a given point, on either a radial flight or on a flight circling the transmitting station

Numerous sudden decreases in signal strength, noted on the recording made while the vertical transmitting antenna and the horizontally polarized tail V receiving antenna were in use, do not show up to as great an extent in the corresponding polar diagram, Fig. 7, as might be expected

It should be observed that each of the polar diagrams is based on a recording made during a single flight and, except for the

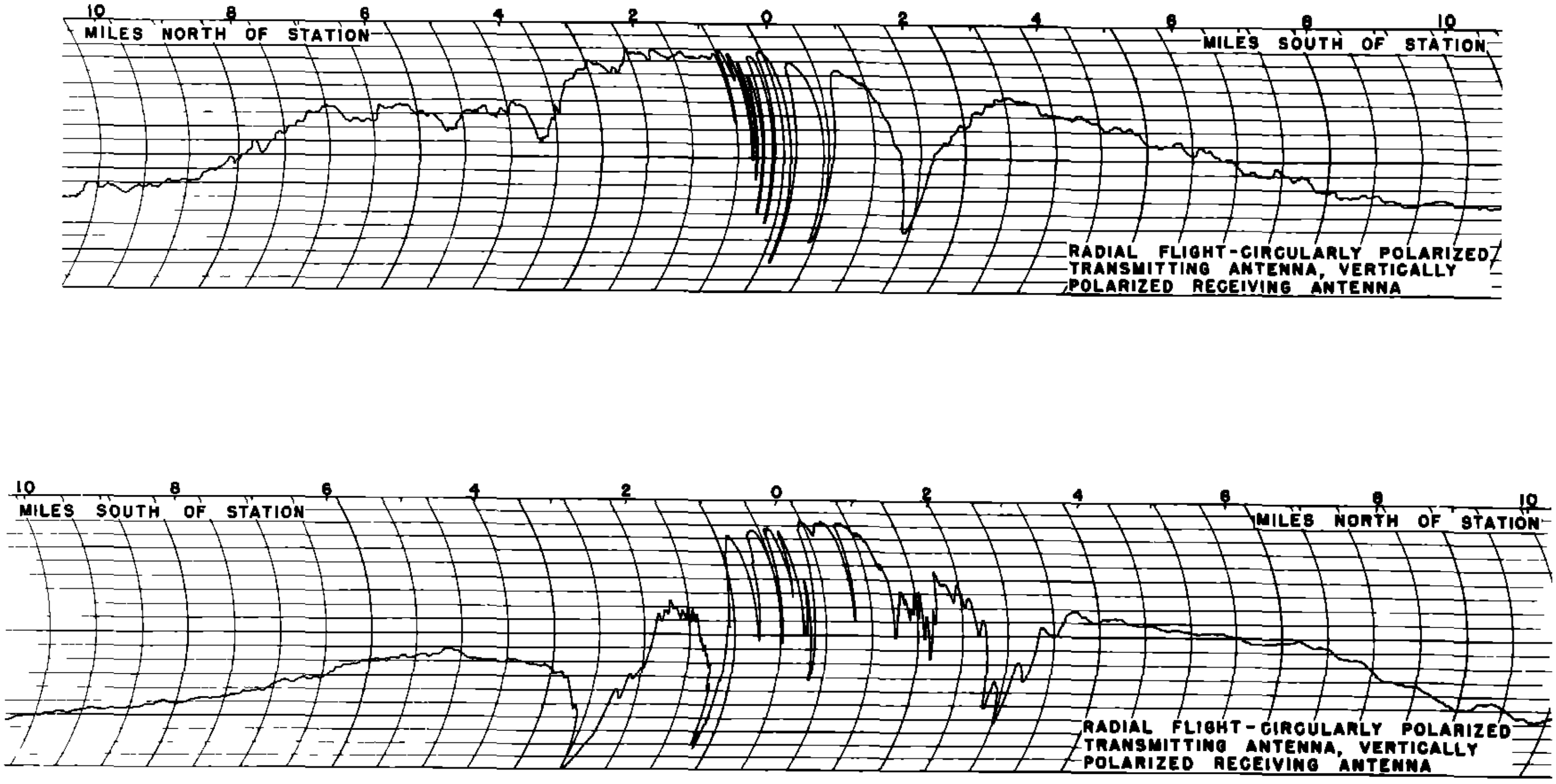

Fig. 5 Recordings of Radial Flights

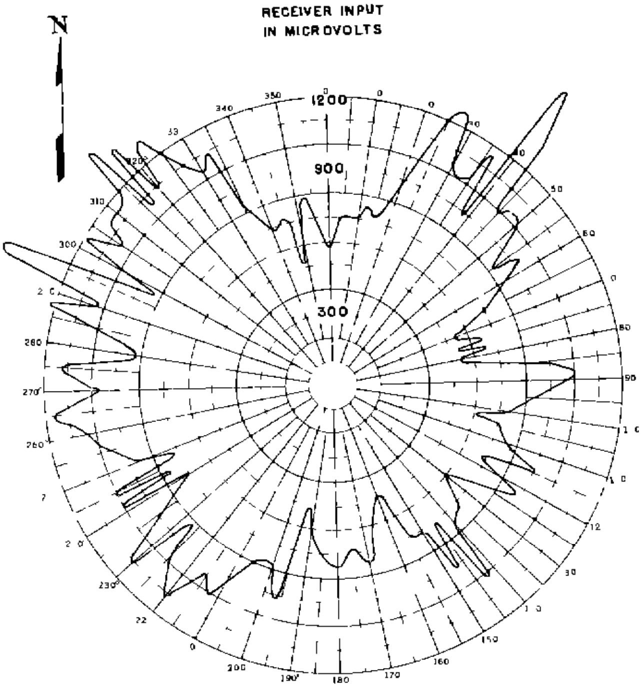

Fig 6 Receiver Input Voltage Using the Vertically Polarized Transmitting Antenna and the Vertically Polarized Receiving Antenna

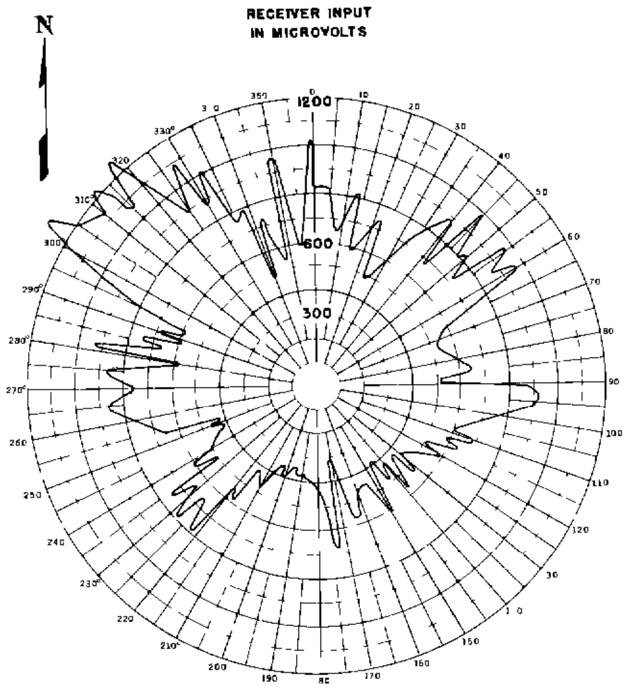

Fig 8 Receiver Input Voltage Using the Circularly Polarized Transmitting Antenna and the Vertically Polarized Receiving Antenna

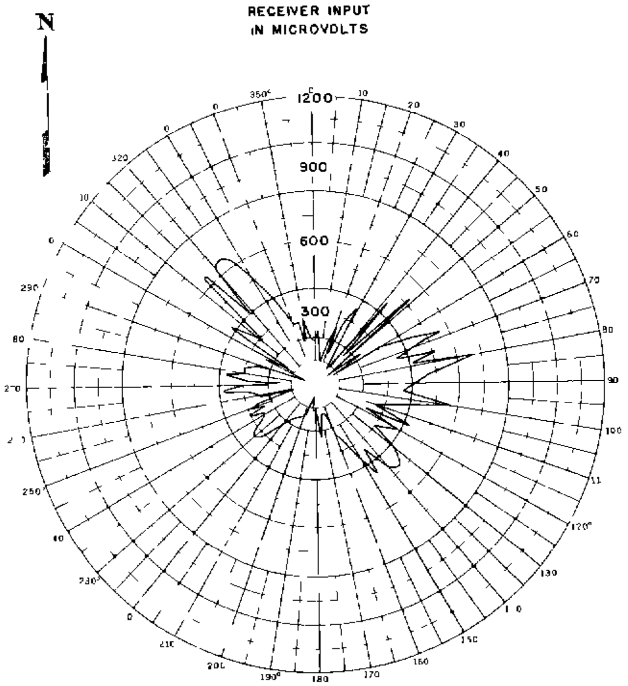

Fig. 7 Receiver Input Voltage Using the Vertically Polarized Transmitting Antenna and the Horizontally Polarized Tail V Receiving Antenna

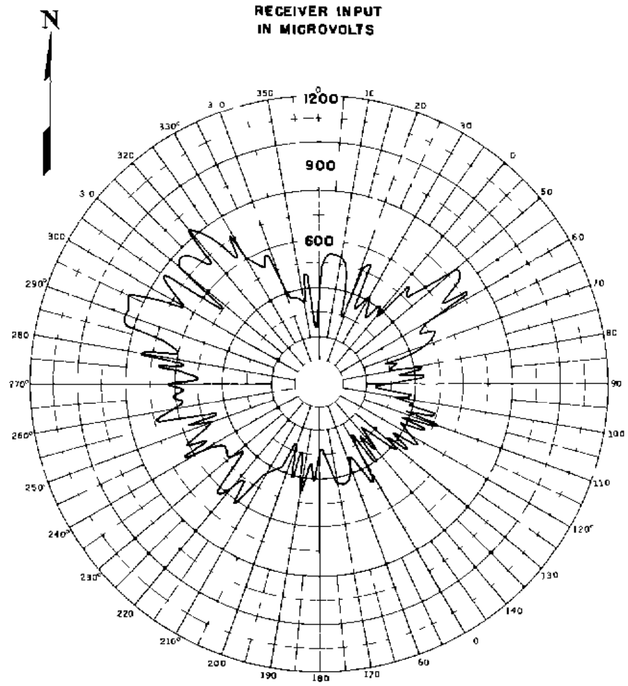

Fig 9 Receiver Input Voltage Using the Circularly Polarized Transmitting Antenna and the Horizontally Polarized Tail V Receiving Antenna

equalizing factor of three applied to recordings made while using the horizontal receiving antenna, no allowances were made for changes in the attitude of the airplane or for small variations in altitude. The recordings are typical of what would be observed on a similar aircraft flying under average conditions.

CONCLUSIONS

The results of these tests show that if the transmitting station uses an antenna which is circularly polarized, communication may be established with aircraft using either vertically or horizontally polarized antennas at nearly as great a distance as when vertically polarized antennas are used on both the control tower and the airplane Horizontally polarized aircraft antennas should not be used for reception of signals from vertically polarized ground transmitting antennas because of the erratic results which are obtained The circularly polarized antenna for control towers satisfies the requirements of both vertically and horizontally polarized receiving antennas