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THE DEVELOPMENT OF TECHNIQUES FOR THE UTILIZATION OF VHF RADIO IN LIGHT AIRCRAFT

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PREFACE

This project was initiated to develop methods of utilizing VHF radio equipment in light aircraft Successful performance of aircraft radio apparatus in the navigation-communication band from 108 to 123 megacycles requires the use of new aircraft equipment design, installation, maintenance and operating techniques The equipment design problems are the primary concern of the engineer who must solve them prior to the manufacture of the apparatus The airborne VHF navigation-communication receiver and VHF transmitter present the airplane manufacturer, the repair station, the owner and the pilot of the airplane with new equipment utilization techniques The aircraft installation problems, which occur in new aircraft and in transition from low frequency to VHF radio apparatus in aircraft now flying, are the major consideration of this report Good VHF radio equipment combined with good VHF radio installations will permit aircraft operating at 1,000 feet or higher to receive reliable navigation and communication signals from the visual omnidirectional radio range stations now being installed by the Federal Airways A sufficient number of these VOR stations will be installed to provide continuous VHF signal coverage to aircraft operating anywhere within the country The VHF aircraft radio flight standards used for the purposes of evaluating this report establish a gauge which may be used by the pilot and by technical personnel After the final implementation of the omnirange ground station program, aircraft VHF installations complying with these minimum flight standards will be capable of receiving continuous navigation and communication signals for all geographic positions of aircraft flying above 1,000 feet

In order to best serve the interests of the light plane owner an economical answer to these problems was sought Accordingly, Electronics Research, Inc of Evansville, Indiana, was given the task of carrying out this project under the sponsorship of the Civil Aeronautics Administration and their final report comprises most of this publication

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CROSS REFERENCE INDEX OF ANTENNA PATTERNS AND FLIGHT TESTS

FLIGHT TESTS

Type Aircraft	Flight No	Type Antenna	Photograph	Pattern	Flight Test	Type Suppression used
Piper Cruiser	1	V-109 over cabin	Fig 30		Table I	Resist plugs
" "	2	" " "	"	Fig 31	Table I, II	Shielded
" "	3	Series stub on starboard wingtip	Fig 20			
Stinson Voyager	4	V-109 over cabin	Fig 32		Table I	Resist wire
" "	5	" " "	"		Table I	Resist plugs
" "	6	" " "	"	Fig 31	Table I, II	Shielded
" "	7	V-109 at rear of cabin		"	Table I	"
Ryan Navion	8	V-109 over vertical stabilizer	Fig 33	Fig 31	Table I, II	Shielded
" "	9	V-109 over cabin		"	Table I, II	"
" "	10	NARCO over cabin	Fig 34	"	Table I, II	"
Beechcraft Bonanza	11	Pioneer over cabin	Fig 35	Fig 31	Table I, II	Shielded
" "	12	V-109 under tail	Fig 36	"	Table I, II	"
Ercoupe	13	V-109 over cabin			Table VI, VII	None
"	14	" " "		Fig 44	Table VI, VII	Resist plugs
Luscombe	15	V-109 over cabin	Fig 45	Fig 44	Table VI, VII	Resist plugs
Swift	16	V-109 over cabin	Fig 48	Fig 44	Table VI, VII	Shielded
Bellanca	17	V-109 over cabin	Fig 50		Table VI, VII	Def Shield
"	18	" " "	"	Fig 44	Table VI, VII	Shielded
Cessna	19	V-109 over cabin	Fig 52		Table VI, VII	Def Shield
"	20	" " "	"	Fig 44	Table VI, VII	Shielded

THE DEVELOPMENT OF TECHNIQUES FOR THE UTILIZATION OF VHF RADIO IN LIGHT AIRCRAFT

INTRODUCTION

This report is a description of the work done by Electronics Research, Inc in fulfilling Contract C13ca-235 of March 4, 1949, with the Civil Aeronautics Administration The contract called for the development of techniques to simplify the utilization of VHF radio equipment in light aircraft

The work program was outlined in the contract as follows

STAGE I

The Contractor shall modify or otherwise extend the range of an acceptable type of low frequency field strength and noise meter to make accurate measurements of noise in the 108-126 Mc band This equipment also shall be modified to permit normal operation with a 12 or 24 v filament supply and motor generator, vibrator or dry cell plate supply

An audio frequency noise meter also shall be modified for operation from the above power supplies

STAGE II

A study pertaining to the placement of readily available types of VHF antennas on each of three aircraft shall be made to determine the best location of these antennas for noise reduction, omnidirectional pattern and overall efficiency Propeller modulation also shall be studied in any trial installations where this effect is likely to manifest itself Locations such as fin top, fuselage, wing, etc shall be studied Satisfactory routing of antenna coaxial lead-in and structural problems concerning antennas also shall be considered Recommendations shall be made as to type of cables to be used as well as their lengths

STAGE III

(a) All convenient locations for the VHF receiver within the three aircraft shall be studied to determine the best locations with respect to noise reduction Various routes for the receiver power control and output leads shall be studied to determine good or bad paths with regard to noise pickup

(b) Measurements shall be made at each location to determine alternate satisfactory locations in addition to the optimum location

STAGE IV

A mock-up of a typical light aircraft electrical system shall be made This mock-up shall consist of a device to simulate a four or six cylinder opposed-type engine and a metal frame to hold those parts of the system not mounted on the engine The mock-up engine shall be provided with spark plug receptacles, power take-offs for magnetos, etc , and shall be constructed so that a minimum of time will be required to substitute magnetos, generators, etc for test purposes

STAGE V

A complete study of unshielded ignition systems shall be made, and techniques in bonding shall be studied with the view to reducing noise in unshielded ignition systems

(a) A study of each electrically operated part in the aircraft and its contribution to the total noise shall be evaluated

(b) Bench tests and mock-up of the entire electrical system of the aircraft and application tests and system evaluation tests in flight shall be made to determine whether a satisfactory installation can be made with an unshielded ignition system

(c) A study of shielded ignition systems shall be made on the three engines, and the reduction of noise between the shielded and unshielded ignition systems shall be evaluated and information submitted to the Civil Aeronautics Administration

(d) A system of shielding for each ignition system on each engine shall be designed for each aircraft

STAGE VI

Flight tests shall be made in light aircraft utilizing three types of engines to determine the results obtained by the Contractor, and the following information shall be submitted

(a) The signal-to-noise ratio measured in all test aircraft

(b) The overall performance of the VHF equipment and the aircraft antenna Performance will be tabulated in the 108 to 126 Mc band, at a range of 45 miles and 1,000 feet altitude

STAGE VII

A "VHF Radio Installation" instruction manual shall be written containing instructions for the installation of VHF radio equipment and the application of noise-reducing techniques to light aircraft

STAGE VIII

The Contractor shall apply the techniques developed to the following types of aircraft Temco, Luscombe, Ercoupe, Cessna, Bellanca, Beech, Navion, Piper Cruiser, and Stinson Installations shall be in accordance with the VHF installation instruction manual These installations shall be used to demonstrate the overall value of the developed methods in the installation of VHF in these types of aircraft, and to check the instruction manual for errors and deficiencies

SUMMARY

Two types of VHF noise intensity meters were constructed by modifying standard equipment The first was made by adding a VHF converter and metering circuits to a Federal Model 101B Field Intensity Meter The second was obtained by using an audio frequency noise voltmeter with a NARCO VRA-1 VHF Aircraft Receiver and associated equipment These instruments were used in later experimental work A full-scale mock-up of a typical small aircraft ignition system was constructed for use in VHF noise studies

Scale model antenna studies and flight tests were made to determine the best location for the VHF receiving antenna on small aircraft It was found that the best location for V-type antennas on most airplanes, from a pattern standpoint, was over the forward part of the cabin

Ignition-noise studies were made, using the mock-up and actual aircraft, resulting in the following conclusions

(1) The main cause of VHF interference on light aircraft is arcing at the spark plugs and subsequent radiation by the high-tension leads connected thereto Other contributions to the VHF noise level may be made by the battery charging generator and by other electrical devices

(2) The location of the VHF receiver and the length of the antenna transmission line is not critical in small aircraft if the aircraft antenna is designed to be properly terminated by the line and receiver

(3) The use of resistance spark plugs without shielded harness provides an economical means of ignition-noise suppression. Satisfactory VHF communication and navigation signals can be received at distances of 45 miles when the aircraft is 1,000 feet above the ground if the VHF receiver contains properly designed noise limiting circuits

(4) Most complete VHF noise suppression is obtained with a properly maintained shielded ignition system

A manual of equipment installation instructions entitled, "VHF Omnirange Radio Installation and Noise Reduction Techniques" is given in Appendix I

STAGE I

INSTRUMENTATION

Stage I of the work program included the modification of a low-frequency field strength meter for noise intensity measurements in the range 108-126 Mc to operate on 12 v dc power supply, and the construction of an audio noise meter

First a Federal Model 101B Field Intensity Meter was altered to function as a VHF noise meter Later a more useful instrument was developed by modifying a NARCO VRA-1 VHF Aircraft Receiver for use with the audio noise meter A description of both modified equipments follows

Modification of Federal Field Intensity Meter

The Federal 101B Field Intensity Meter selected for modification consists essentially of a radio receiver whose sensitivity can be calibrated by means of an integral signal generator Plug-in loop antennas are available for the frequency ranges 200-400, 550-1600, 1600-3600 and 3600-7000 kc

The following changes were made in this instrument to adapt it for use in making noise intensity measurements in the frequency range 108-126 Mc See Figs 1, 2 and 3

1 An external VHF converter for the loop antenna socket of the field intensity meter

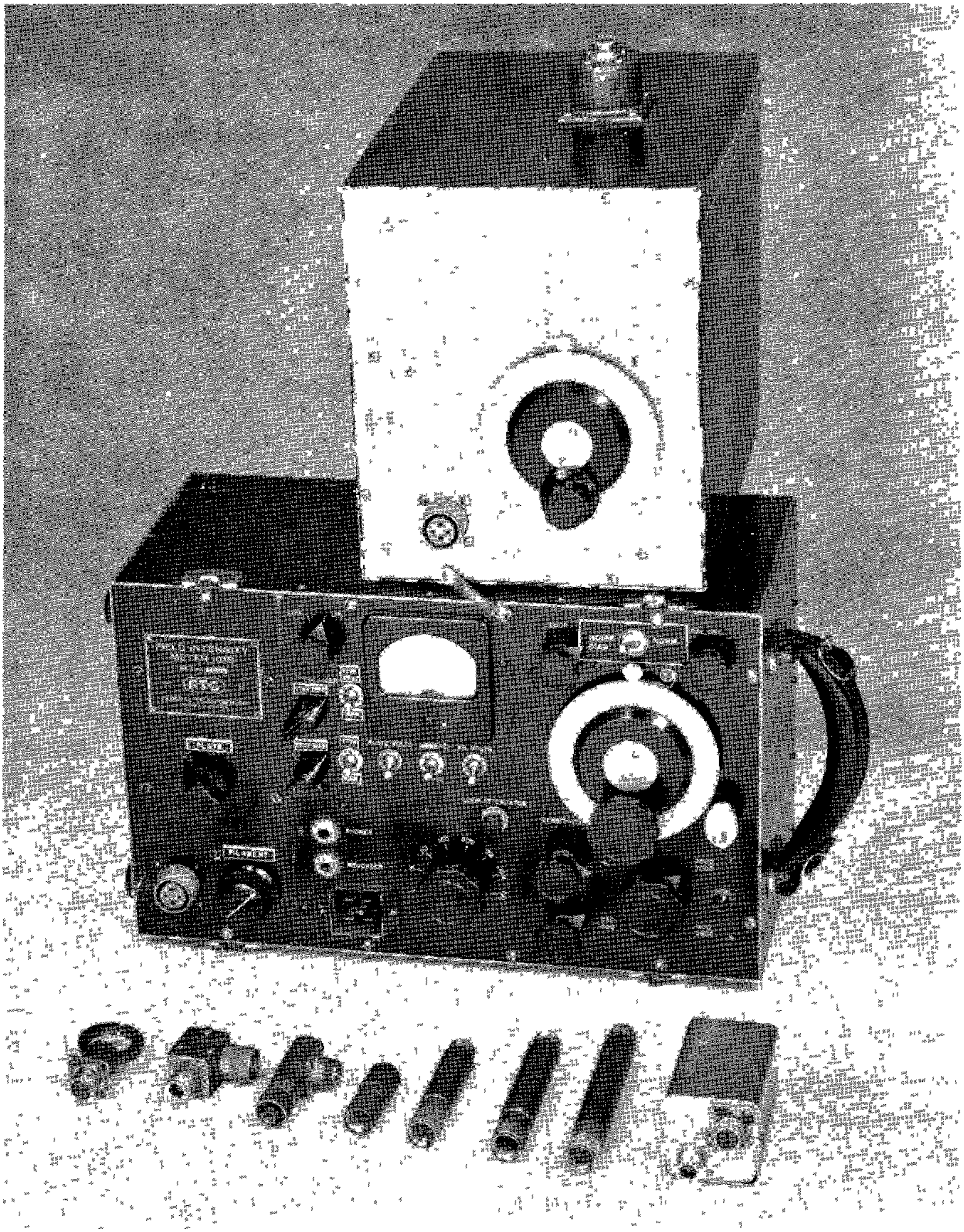


Fig 1 Federal 101B Field Intensity Meter After Modification

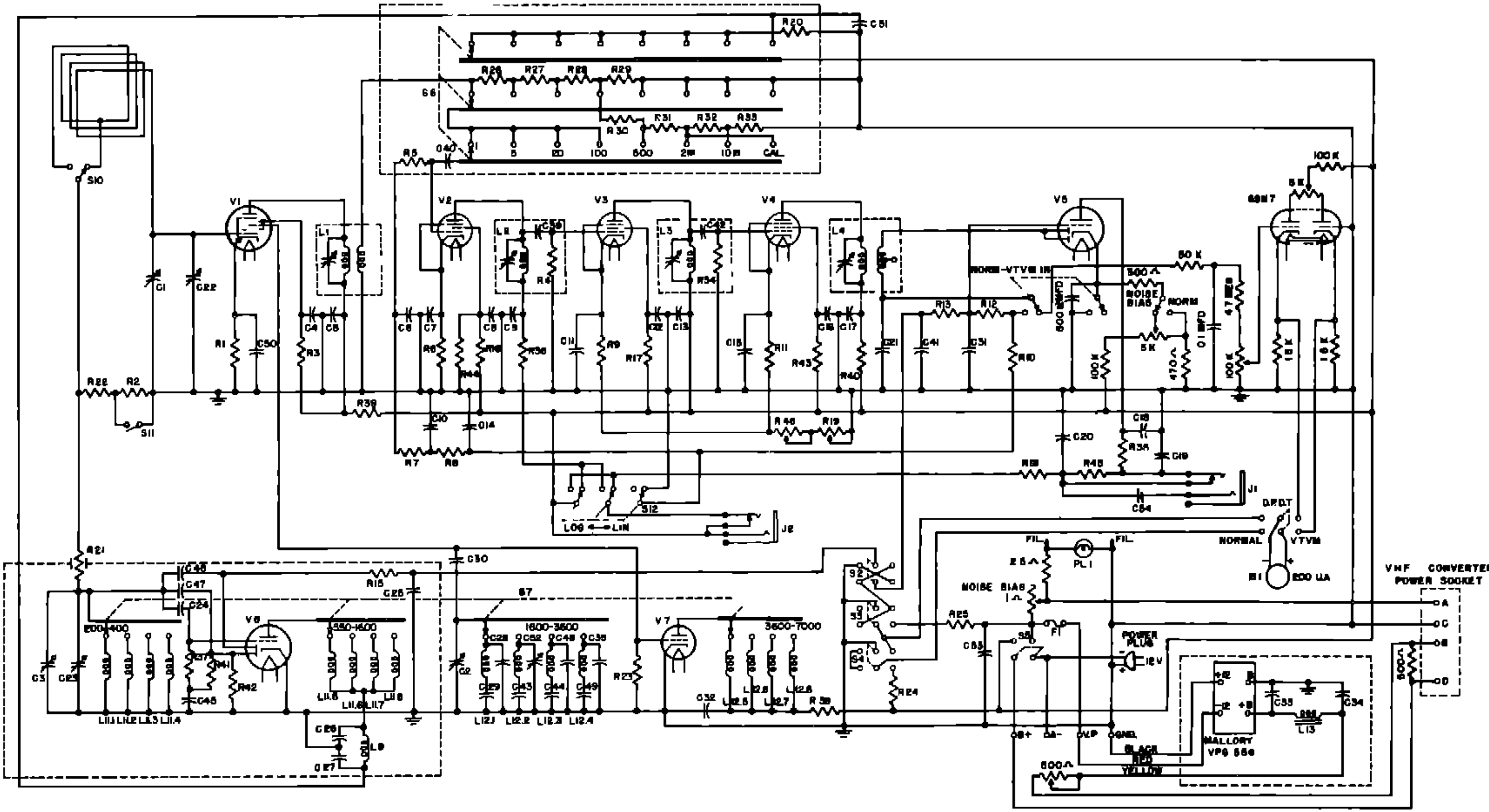


Fig 2 Federal 101B Field Intensity Meter After Modification

was constructed This converter uses a pair of 6J4 tubes in a push-pull grounded-grid input circuit to provide a good termination for a 100-ohm balanced transmission line These 6J4's feed a 6J6 first mixer stage having an intermediate frequency output of 30 Mc A 6C4 is used as local oscillator for the first mixer A stage of 30 Mc intermediate frequency amplification using a 6AK5 tube, and 6BE6 second mixer-oscillator with an intermediate frequency output of 3 5 Mc for the field intensity meter are provided

2 The power supply in the field intensity meter was replaced by a Mallory Type VP-G 556 Vibrapack to permit operation from a 12-v aircraft battery

3 A vacuum-tube voltmeter weighing circuit was incorporated in the basic field intensity meter with provision for switching it into the output of the detector to measure peak noise Voltmeter time constants of 10 milliseconds on charge and 600 milliseconds on discharge were provided

4 Filament and plate voltage regulating rheostats were added A connector was installed to provide plate and filament voltage to the external VHF converter

5 Three fixed plug-in input attenuator pads were constructed to insure linear operation with high radio frequency input voltages A balun for unbalanced input transmission lines and a current probe to aid in the location of noise signal sources were also provided Schematic diagrams of these accessories are included in Fig 3

The modified equipment, hereafter referred to as the ERI-Federal VHF noise meter, has better than one microvolt sensitivity in the range 108-126 Mc, sensitivity being defined as the unmodulated radio frequency input required to double the meter deflection due to residual noise Image responses are down approximately 35 db The bandwidth is less than 10 kc, limiting the usefulness of the instrument in the VHF region

Modification of NARCO VHF Receiver

Little difficulty was experienced in modifying a NARCO (National Aeronautical Corporation) Model VRA-1 VHF Receiver to function as a VHF noise intensity meter However, it was found that satisfactory results could not be obtained by simply connecting an audio noise voltmeter across the receiver audio output, mainly because of the noise limiting and avc circuits Other modifications were investigated and the system which proved satisfactory involved using an audio noise voltmeter at the omnioutput jack of the NARCO Receiver The receiver avc circuit was disabled by shorting condenser C33, Fig 4 This method required the construction of an external audio noise meter Two types of audio noise meters were built and are described herein

Audio Noise Meters

Any high-impedance audio frequency voltmeter having the proper damping and frequency characteristics is satisfactory for employment with the NARCO Receiver as outlined previously The meter damping required in a study of aircraft ignition noise is related to the speed of the aircraft engine involved, the noise consisting essentially of sharp pulses produced by the magneto Suitable damping constants are a 10 millisecond rise and 600 millisecond decay time for the indicating meter

The first type of audio frequency noise meter constructed employed a weighing circuit having the aforesaid time constants, and was designed for use with an external vacuum-tube voltmeter such as the RCA Voltohmyst See Figs 5A and 6 In this circuit the charge time is determined by R1 and C2 and the discharge time by R2 and C2 The condenser C1 is necessary to block the dc voltage appearing at the omnijack of the NARCO Receiver The diode D1 serves as a dc restorer maintaining negative voltage pulses The series diode D2 is used to permit charging of condenser C2 through the low impedance path R1, and to maintain the high resistance discharge circuit for this condenser

The second audio frequency noise meter constructed consisted of the weighing circuits just described and a battery-operated vacuum-tube voltmeter contained in a single case Output terminals were provided for an external 100 microampere meter, such as is available in the Simpson Type 260 Multimeter, to be used as an indicator See Figs 5B and 6 A two position switch, S1, provides full-scale sensitivities of 2 5 and 10 v

Performance Tests

Linearity and frequency-response tests

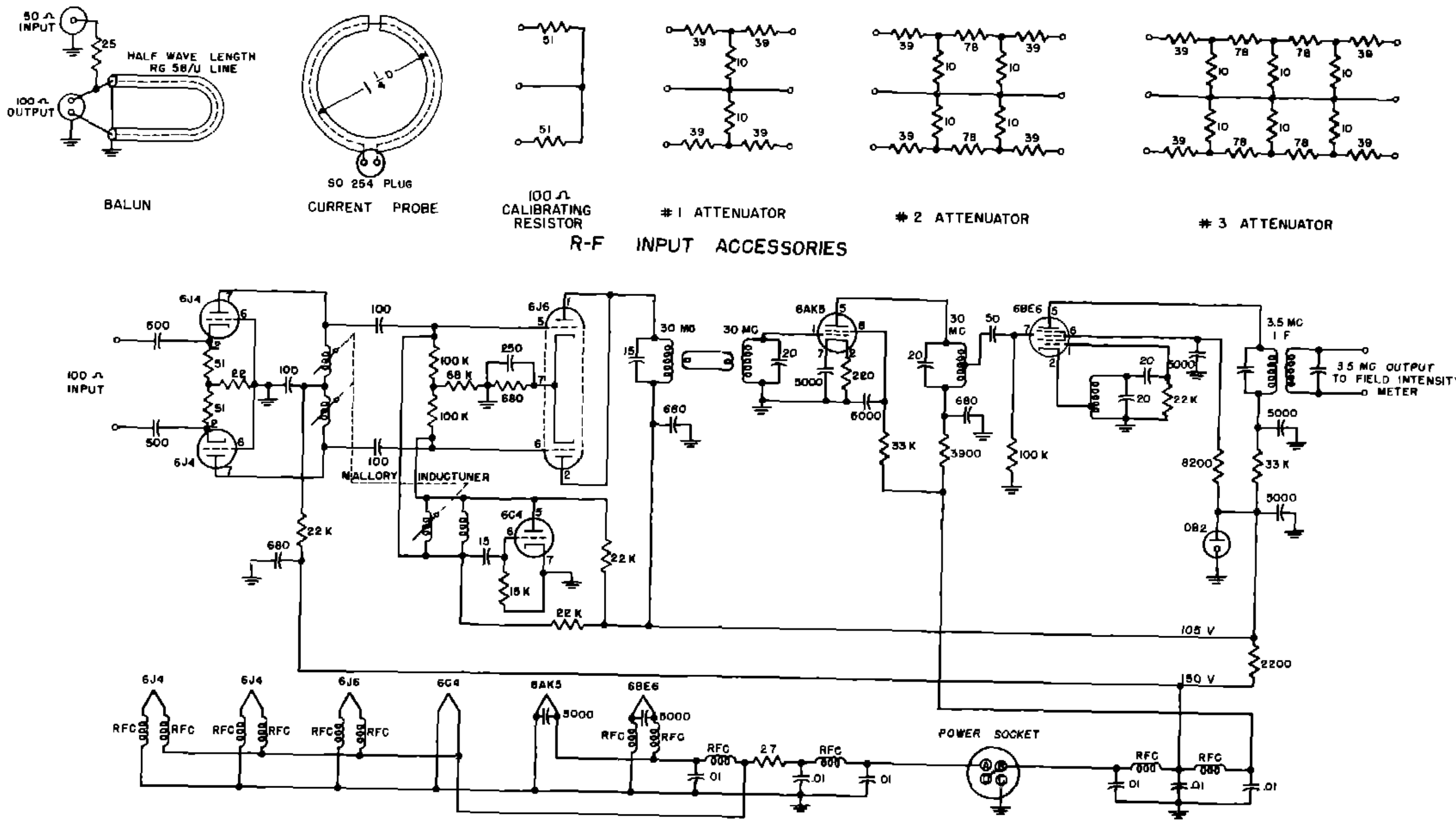


Fig 3 VHF Converter for Federal Field Intensity Meter

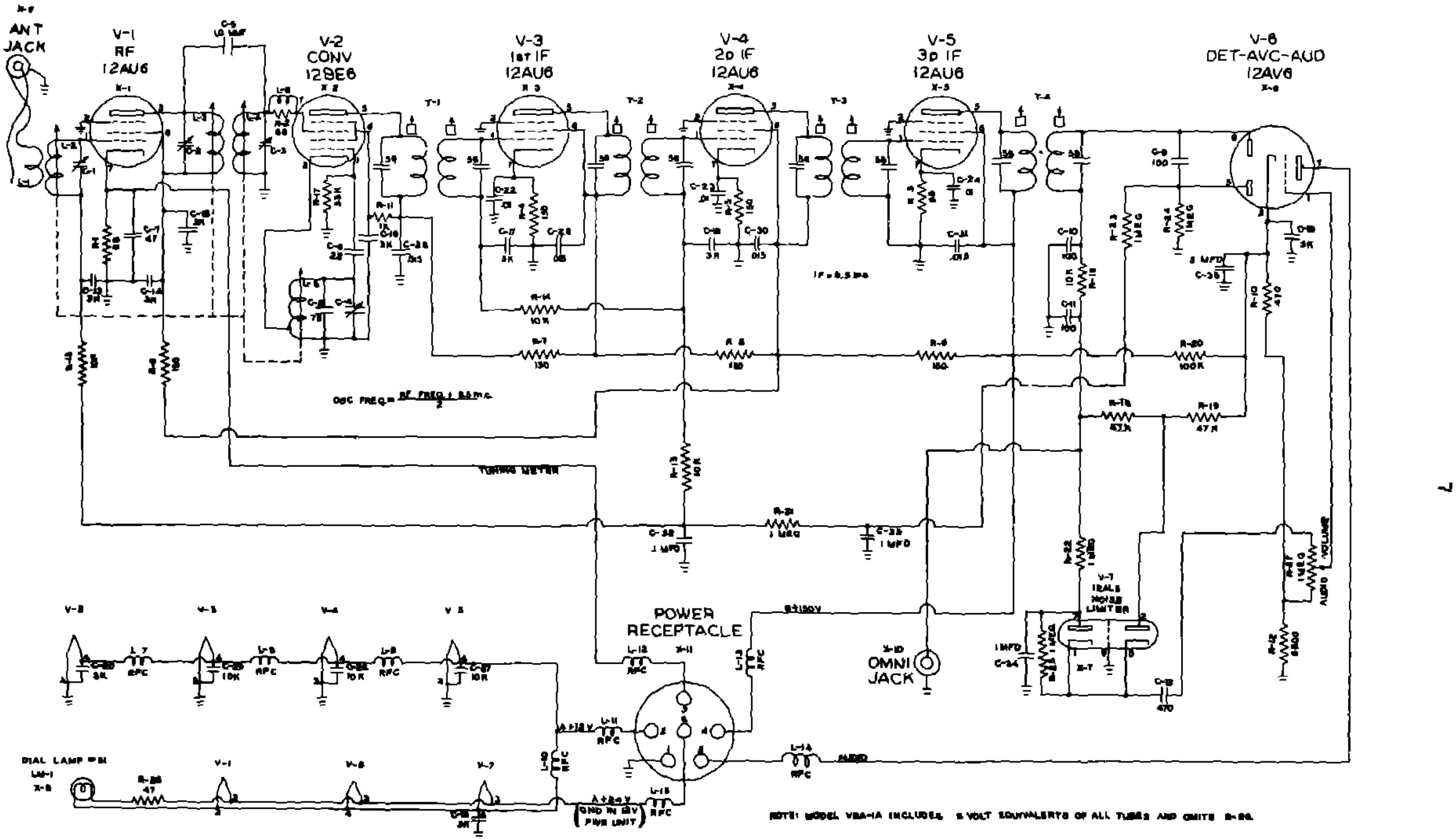
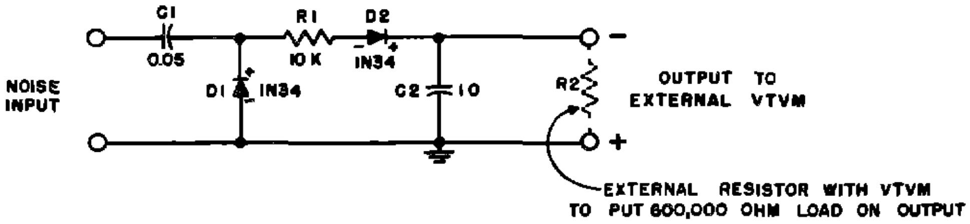
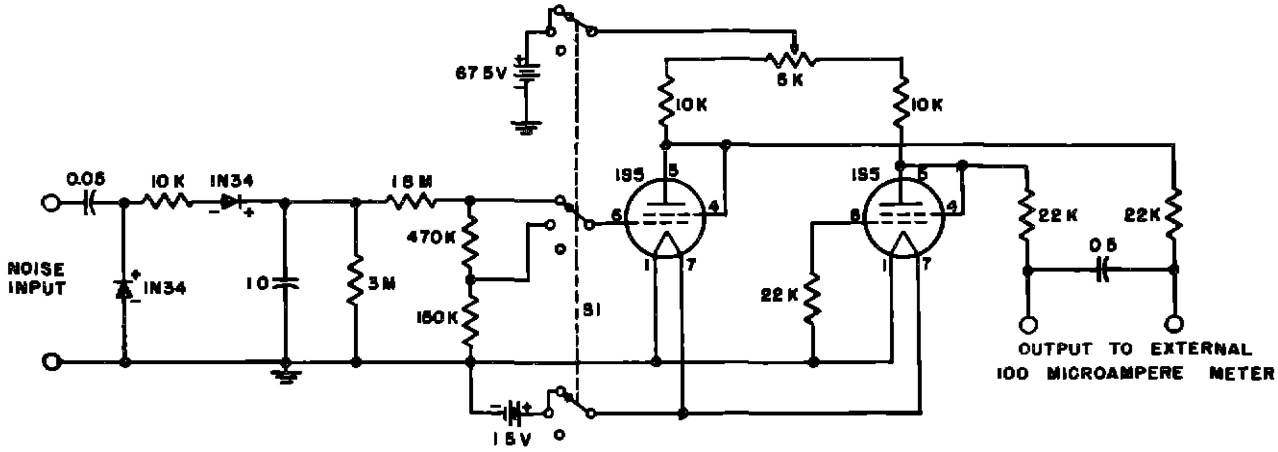


Fig 4 NARCO VRA-1 Receiver



(A) CRYSTAL TYPE



(B) VACUUM-TUBE TYPE

Fig 5 Audio Noise Meters

were made on the vacuum-tube audio frequency noise meter just described, using a Hewlett-Packard Model 200D Audio Oscillator and a Measurements Corp Model 62 ac Voltmeter These tests confirmed that the instrument was linear over the range of the 100 microampere output meter employed (Simpson Model 260) The frequency response was flat from 500 to over 10,000 cps and was about 3 db down at 45 cps

An overall linearity check was made on the NARCO Receiver and vacuum-tube noise meter, using a Measurements Corp Model 80 Signal Generator as a standard signal source Information was obtained for the curve Fig 7

STAGE II

ANTENNA LOCATION STUDY

Stage II of the work program called for a placement study of readily available types of VHF antennas on three aircraft to determine the best locations for noise reduction, radiation pattern and overall efficiency The effects of propeller modulation were considered in those antenna locations which appeared vulnerable to this effect Lead-in problems were also studied

An extensive scale-model antenna-pattern study was made of the CAA Type V-109 antenna on the Piper Cruiser This was followed by flight tests involving a number of antenna installations on the following four types of aircraft Piper Cruiser Stinson Voyager, Ryan Navion and Beechcraft Bonanza

PIPER CRUISER MODEL STUDY

Technique

It is well known that it is difficult to make accurate antenna-pattern measurements on actual aircraft, but that acceptable results can be obtained in studies involving scale

Fig 6 Audio Noise Meters

models of the aircraft and proportional scaling of the wavelengths associated with the antennas involved In order that the most advantageous location for the CAA V-109 antenna on the Piper Cruiser aircraft might be ascertained, a 1/12 size scale model of the aircraft and antenna was made A model of this size was suitable for use on the model range of Electronics Research, Inc since the pattern measurements could be made at 12 times the normal operating frequency of 118 Mc or approximately 1,420 Mc See Fig 8 This model technique made it relatively easy to check the performance of a large number of antenna arrangements (Fig 9) on the Piper Cruiser

The aircraft scale model antenna measuring range employs suitable receivers and transmitters for the frequencies used The model being tested is mounted on an insulated pedestal and rotated in the desired plane by means of an electrical and mechanical system The model aircraft and antenna under study is rotated through 360° planes around three

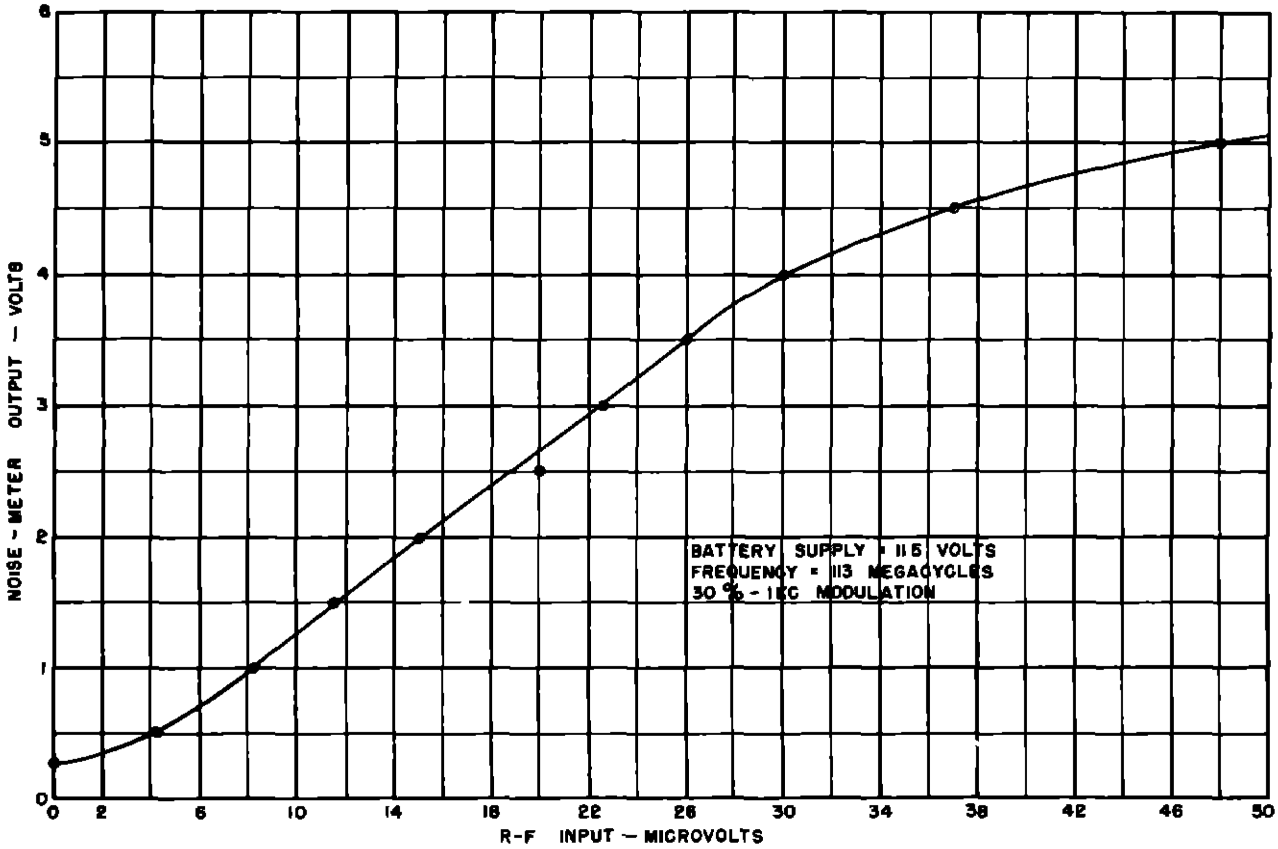


Fig 7 ERI-NARCO VHF Noise Meter Linearity Curve

axes in a uniformly illuminated radio frequency field at the scale wavelength to obtain the spherical performance of the antenna Automatic recording of the scale model antenna signals continuously plots the received antenna voltage throughout the rotation in each plane The plane and axis terminology used in making polar antenna patterns is given in Fig 10 On antenna patterns, the word "cross" used to describe polarization of antennas indicates that the polarization of the transmitting antenna is vertical with respect to the horizontal receiving antenna This is a measure of the aircraft antenna response to cross-polarized signals

In examining the antenna patterns shown in this report, it is well to keep in mind the characteristics desired in a VHF aircraft antenna The pattern in the horizontal plane (Plane 1, Fig 10) should be free from deep nulls, and the signal pickup in the forward and rearward directions should be comparatively uniform and of a high level The signal pattern in the vertical planes (Planes 2 and 3, Fig 10) should be free from deep nulls for at least 15° below the horizontal The antenna response to cross-polarized signals should be at a minimum

CAA V-109 Antenna

The first pattern tests made were on a full-scale model of the CAA Type V-109 antenna at 115 Mc These tests were made to determine the free-space characteristics of this conventional type of antenna

Fig 11 showing the patterns obtained on the V-109 antenna confirms that it has acceptable characteristics Pattern 1 for the horizontal plane (Plane 1, Fig 10) shows that the response is concentrated fore and aft as desired Pattern 1B for the fore-and-aft vertical plane (Plane 2, Fig 10) shows the desired freedom from downward nulls, but that about half of the antenna pickup is directed uselessly in an upward direction Pattern 1D for the vertical plane athwartship (Plane 3,

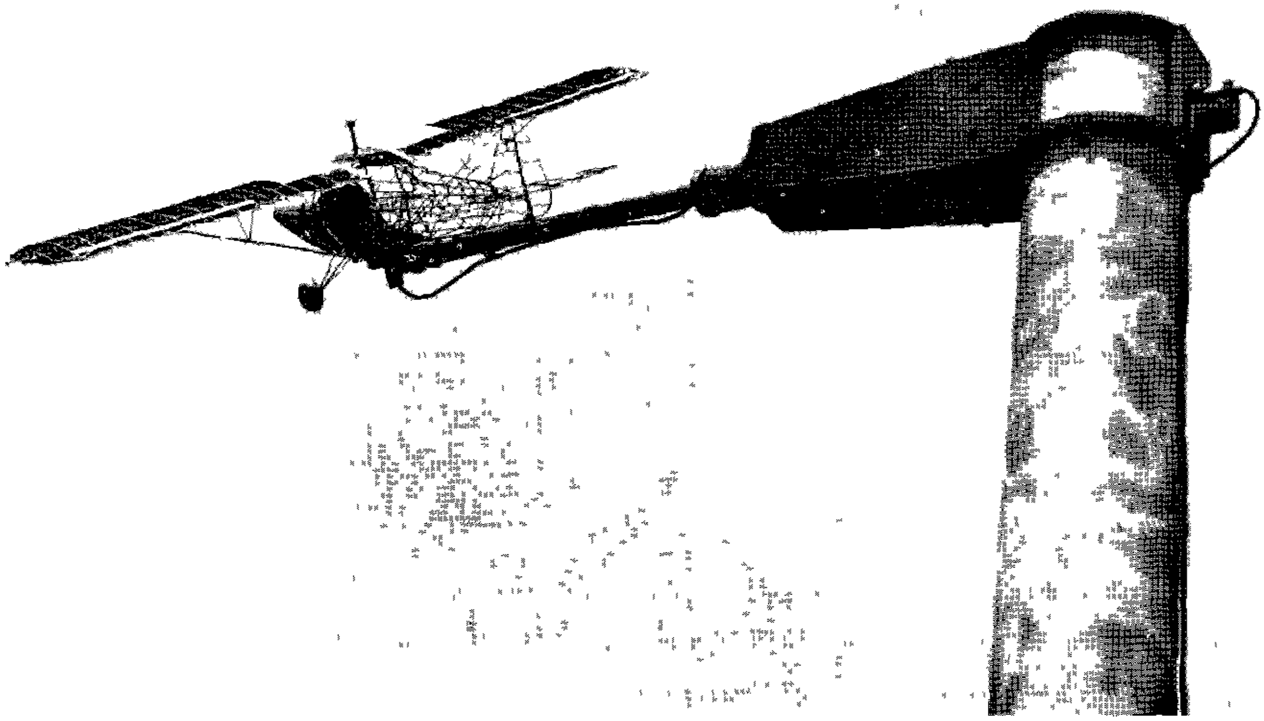


Fig 8 Piper Cruiser Model Test

Fig 10) shows most of the received energy is from below the aircraft with nulls to the side which are somewhat deeper than desired Cross-polarization measurements for the three planes, Patterns 1A, 1C and 1E indicate that cross-polarized radiation is negligibly small

CAA V-109 Antenna Without Pedestal

The vertical supporting pedestal was removed from the V-109 antenna exposing the balun and a pattern study similar to that on the complete antenna was made The patterns obtained (Fig 12) show that receiving characteristics were not impaired by the alteration This can be seen by comparing the corresponding curves in Figs 11 and 12 A small increase in cross-polarized radiation in Plane 1 and Plane 2 was measured, along with a small decrease in Plane 3 The increased cross-polarized signal reception in the modified antenna was probably due to the exposed balun The modified antenna appears to be satisfactory

V-109 Antenna on Piper Cruiser Model, Location 3

Pattern measurements were made with the 1/12 scale model of the Piper Cruiser and V-109 antenna with the antenna at a point above the forward part of the cabin (Location 3, Fig 9) The patterns obtained are given in Fig 13 for comparison with the free-space patterns for the same antenna (Fig 11) Pattern 3 for Plane 1 is similar to the free-space pattern and is satisfactory While the patterns show large upward lobes, there still is appreciable reception in useful directions Pattern 3D, with deep downward nulls, again indicates shielding by the fuselage The cross-polarization patterns, 3A, 3C and 3E, are satisfactory Patterns 3F and 3G were taken with the aircraft in a position simulating flight directly toward and away from the illuminating antenna with the aircraft rotating on its fore-and-aft axis (Axis 4, Fig 10) simulating a 360° roll of flight These two patterns are not of great significance, the nulls being due to cross polarization

The patterns of Fig 13 indicate that this antenna location (Location 3, Fig 9) is satisfactory There is considerable shielding by the metal structure of the aircraft, causing appreciable useless upward antenna sensi-

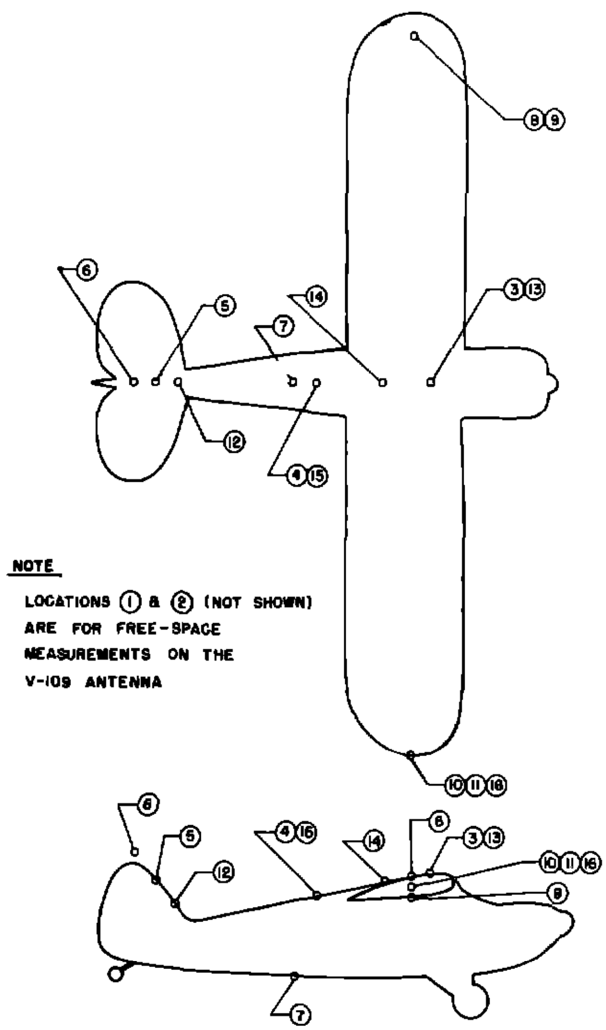


Fig 9 Antenna Test Locations on Piper Cruiser Model

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V-109 Antenna on Piper Cruiser Model, Location 4

Fig 14 gives the patterns obtained with the V-109 antenna mounted just back of the cabin on the Piper Cruiser (Location 4, Fig 9) The patterns show that this location is a poor one because of the deep nulls to the rear in Patterns 4 and 4B and the comparatively large cross-polarized pickup shown in Patterns 4A and 4E

V-109 Antenna on Piper Cruiser Model, Location 5

Fig 15 shows the patterns obtained with the V-109 antenna mounted on the Piper Cruiser Model at a point at the top of the stationary section of the vertical stabilizer (Location 5, Fig 9) Inasmuch as this location had been used on larger aircraft with good results, it was thought desirable to investigate this position for the antenna on the Piper Cruiser

The model range measurements indicate that this location is unsatisfactory due to the deep forward null in Patterns 5 and 5B Pattern 5D, by itself, indicates generally acceptable characteristics

V-109 Antenna on Piper Cruiser Model, Location 6

Patterns obtained with the V-109 antenna mounted above the vertical stabilizer on the Piper Cruiser (Location 6, Fig 9) are given in Fig 16 This installation would be rather impractical on a Piper Cruiser because the whole top portion of the vertical stabilizer is part of the hinged rudder, but a similar location might be available on other makes of aircraft

The patterns show that Location 6 is much better than Location 5, but also has several undesirable characteristics The concentration of antenna sensitivity toward the rear shown in Pattern 6 and the deep forward null in Pattern 6B are hardly acceptable Cross-polarization sensitivity (Patterns 6A, 6C and 6E) is acceptably small

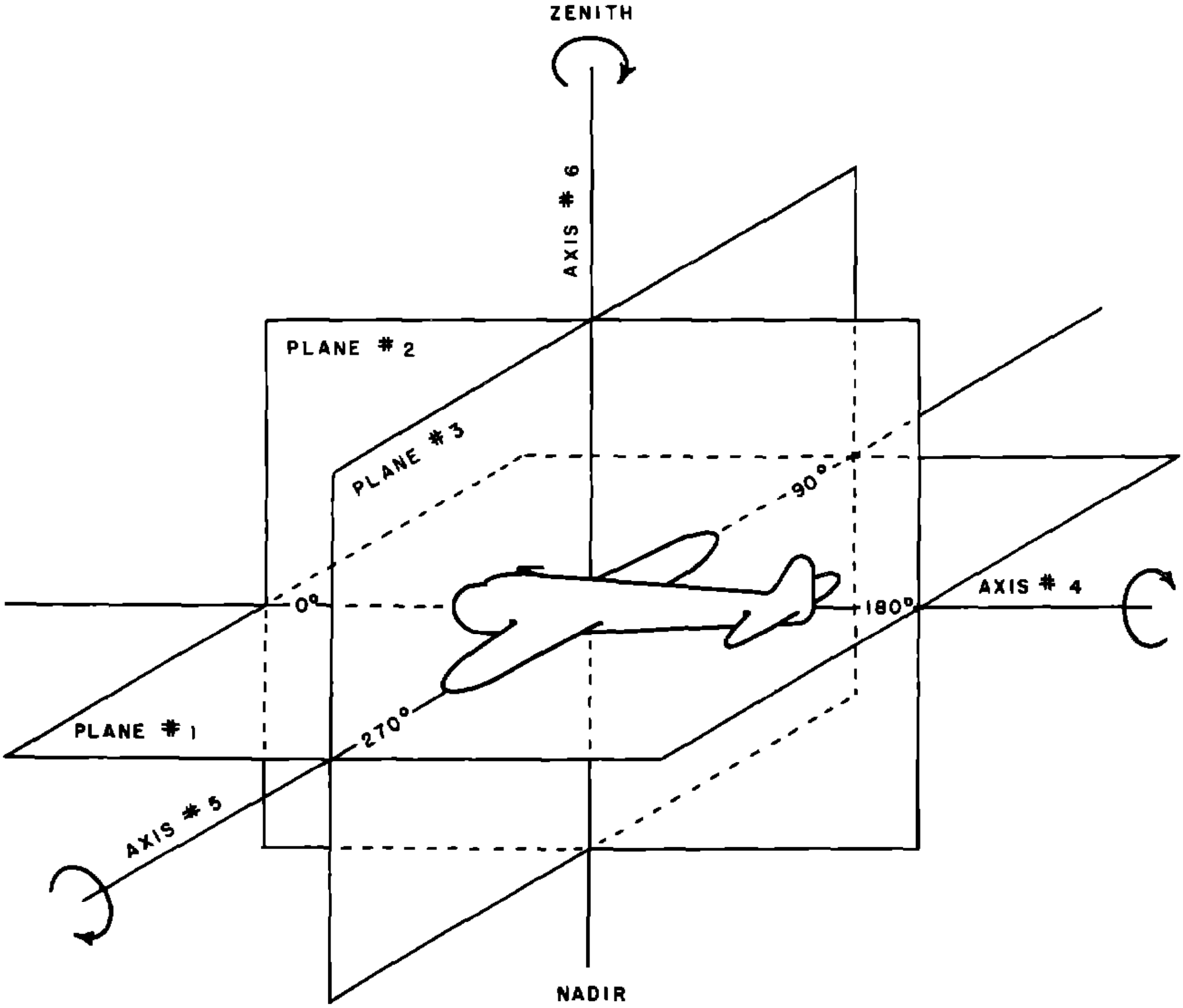
V-109 Antenna on Piper Cruiser Model, Location 7

Fig 17 gives the patterns obtained with the V-109 antenna mounted below and behind the cabin, flush with the fabric skin on the Piper Cruiser (Location 7, Fig 9) An antenna of this type could be painted on the fabric with conducting paint or consist of a metal foil element on the fabric

The deep forward nulls and irregularities in Patterns 7 and 7B make this location unacceptable Response to cross-polarized signals (Patterns 7A, 7C and 7E) is too great

V-109 Antenna on Piper Cruiser Model, Location 8

The V-109 antenna was mounted at a position on the upper side of the port wing of the Piper Cruiser (Location 8 Fig 9) Again the antenna elements were flush with the fabric Fig 18 gives the results obtained at this installation



PLANE OR AXIS

1 = HORIZONTAL PLANE
2 = FORE & AFT VERTICAL PLANE
3 = ATHWARTSHIP VERTICAL PLANE
4 = FORE & AFT ROTATION AXIS
5 = ATHWARTSHIP ROTATION AXIS
6 = VERTICAL ROTATION AXIS

MANEUVER TO PRODUCE PATTERN

360° ROTATION AROUND ZENITH-NADIR AXIS # 6
360° ROTATION AROUND 90° — 270° AXIS # 5
360° ROTATION AROUND 0° — 180° AXIS # 4

PATTERNS FOR PLANE # 1 ARE MADE BY ROTATING AIRCRAFT OR ANTENNA ABOUT AXIS # 6 WHILE THE RADIATED SIGNALS FROM AN EXTERNAL SOURCE ARE PROPAGATED ALONG AXIS # 4

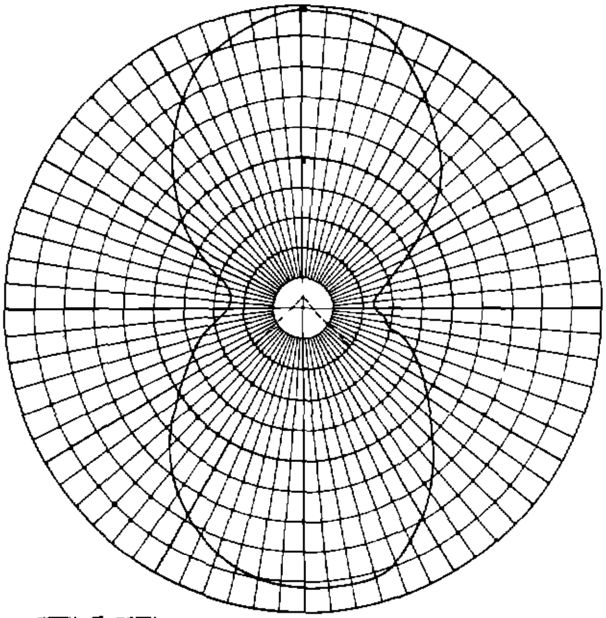
PATTERNS FOR PLANE # 2 ARE MADE BY ROTATING AIRCRAFT OR ANTENNA ABOUT AXIS # 5 WHILE THE RADIATED SIGNALS ARE PROPAGATED ALONG AXIS # 4

PATTERNS FOR PLANE # 3 ARE MADE BY ROTATING AIRCRAFT OR ANTENNA ABOUT AXIS # 4 WHILE THE RADIATED SIGNALS ARE PROPAGATED ALONG AXIS # 5

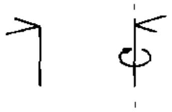
NORMAL PATTERNS USE HORIZONTAL POLARIZATION OF RADIATED SIGNAL.

"CROSS" PATTERNS USE VERTICAL POLARIZATION OF RADIATED SIGNAL

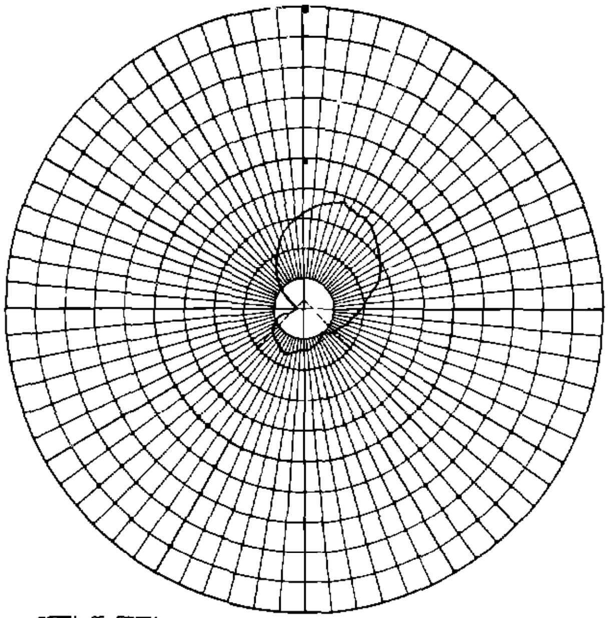
Fig 10 Plane And Axis Terminology for Aircraft Antenna Field Patterns



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

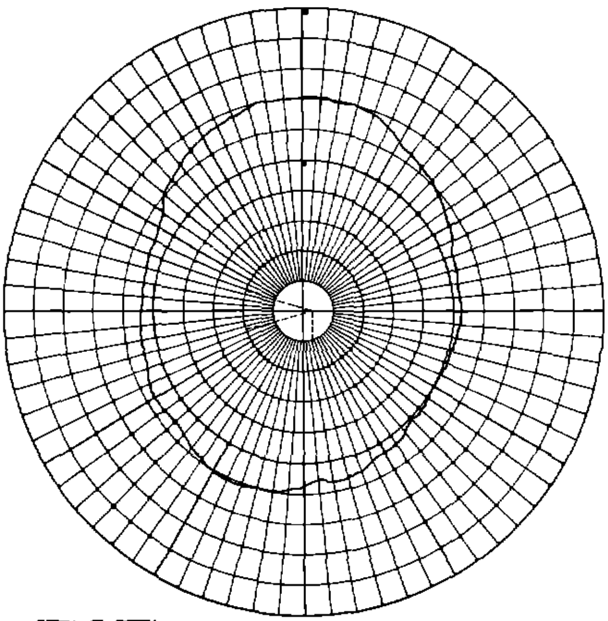


ANTENNA TYPE	Free Space Of V With Pedestal
PATTERN NO.	1
AXIS OF ROTATION	No. 6
POLARIZATION OF ANTENNA	Plane No 1
FREQUENCY	115 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

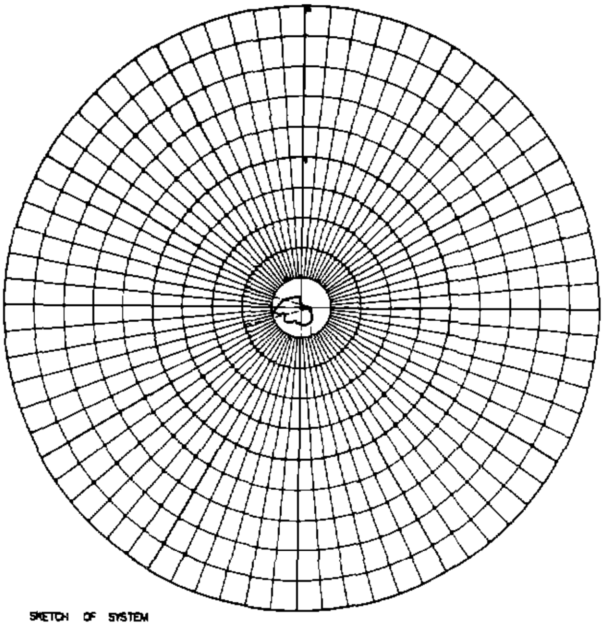
ANTENNA TYPE	Free Space Of V With Pedestal
PATTERN NO.	1 A
AXIS OF ROTATION	No 6
POLARIZATION OF ANTENNA	Plane No 1 Cross
FREQUENCY	115 Mc



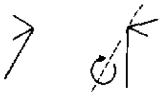
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE	Free Space Of V With Pedestal
PATTERN NO.	1 B
AXIS OF ROTATION	No 5
POLARIZATION OF ANTENNA	Plane No. 2
FREQUENCY	115 Mc

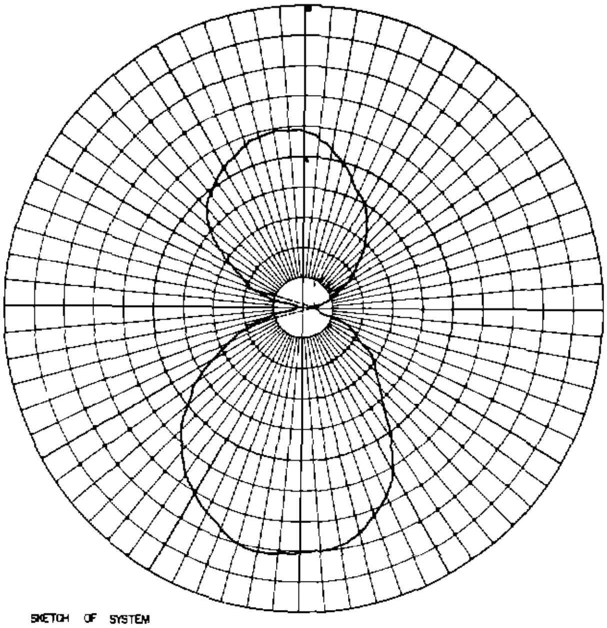
Fig 11 CAA V-109 Antenna Free-Space Patterns



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

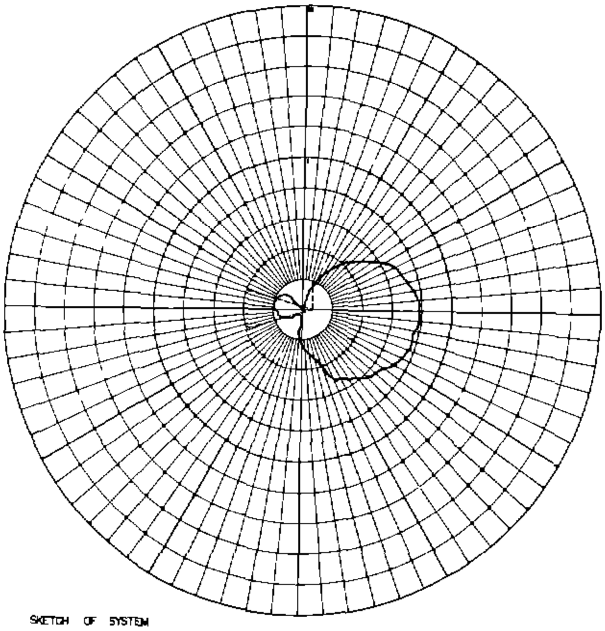


ANTENNA TYPE	Free Space Of V With Pedestal
PATTERN NO.	1 C
AXIS OF ROTATION	No 5
POLARIZATION OF ANTENNA	Plane No 2 Cross
FREQUENCY	115 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

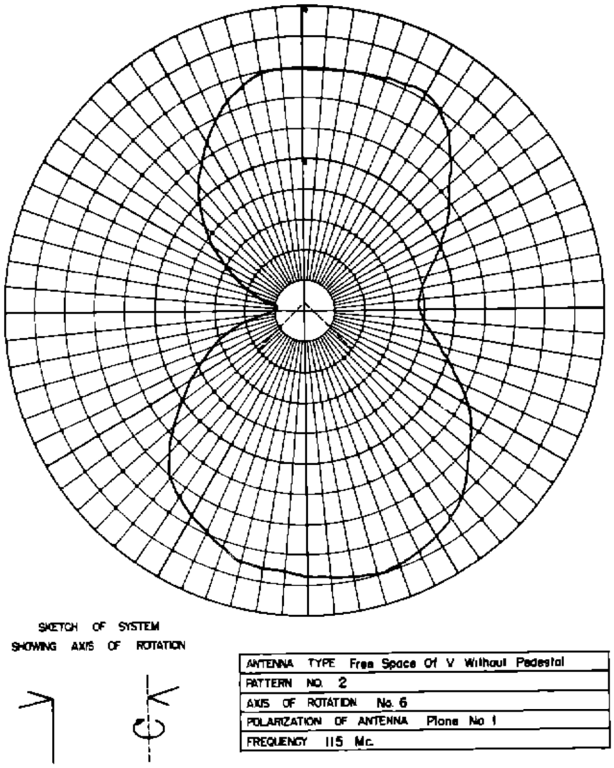
ANTENNA TYPE	Free Space Of V With Pedestal
PATTERN NO	1 D
AXIS OF ROTATION	No 4
POLARIZATION OF ANTENNA	Plane No. 3
FREQUENCY	115 Mc

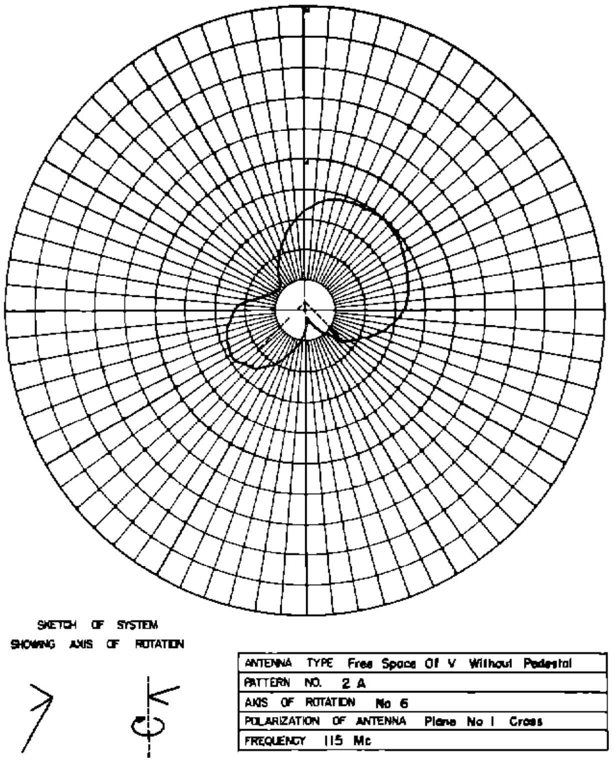


SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE	Free Space Of V With Pedestal
PATTERN NO.	1 E
AXIS OF ROTATION	No. 4
POLARIZATION OF ANTENNA	Plane No 3 Cross
FREQUENCY	115 Mc

Fig 11 (Continued)





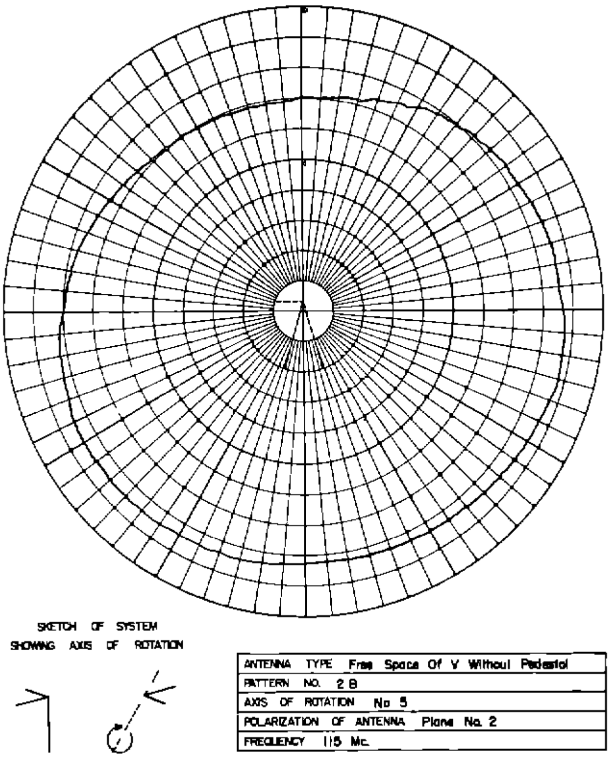
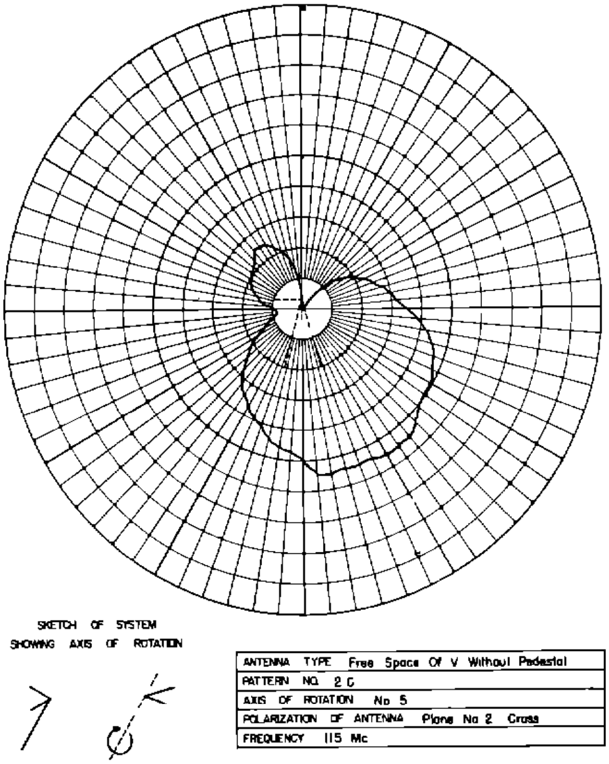
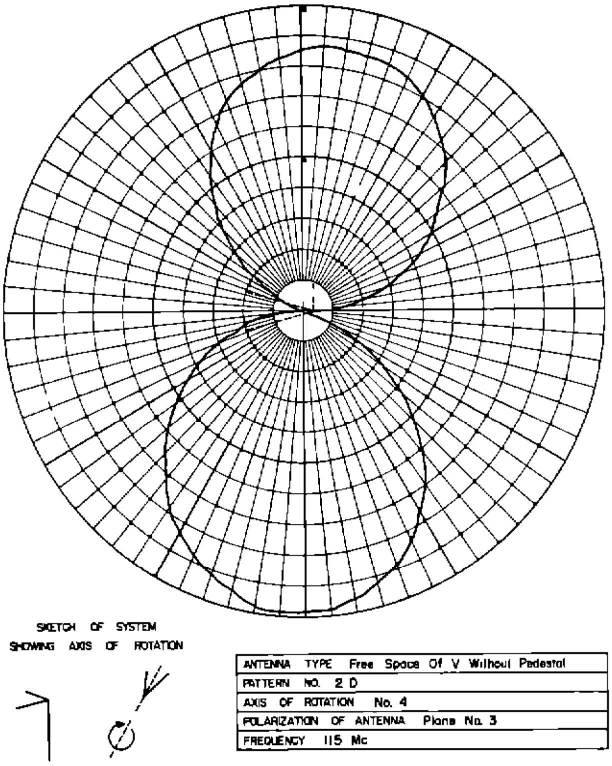


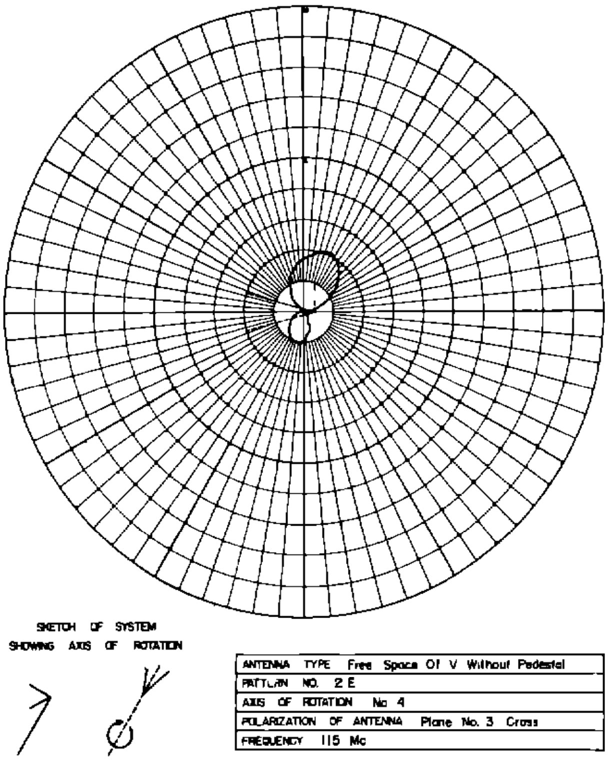
Fig 12 CAA V-109 Antenna With Pedestal Removed



ANTENNA TYPE Free Space Of V Without Pedestal
PATTERN NO. 2 C
AXIS OF ROTATION No 5
POLARIZATION OF ANTENNA Plane No 2 Cross
FREQUENCY 115 Mc

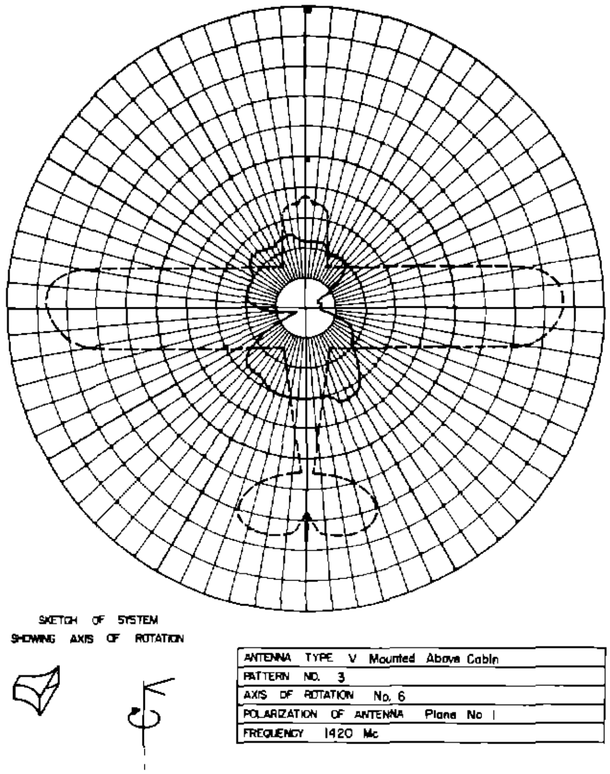


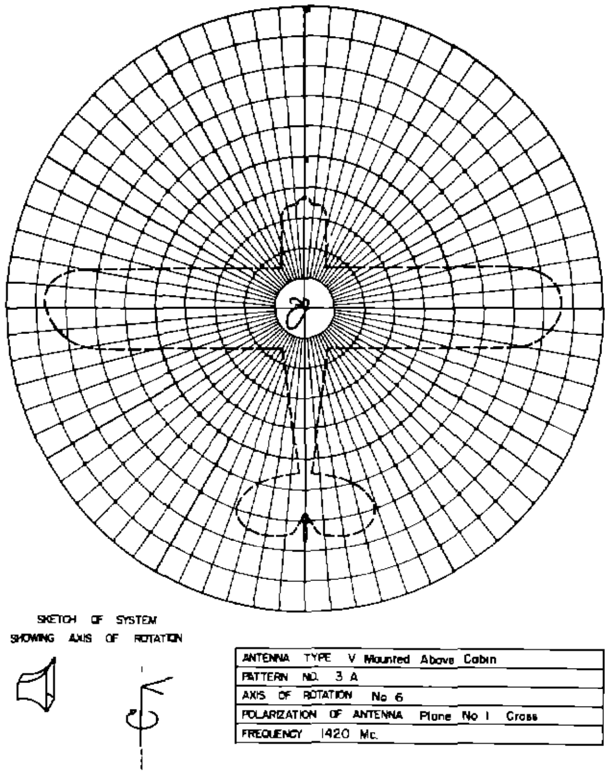
ANTENNA TYPE Free Space Of V Without Pedestal
PATTERN NO. 2 D
AXIS OF ROTATION No. 4
POLARIZATION OF ANTENNA Plane No. 3
FREQUENCY 115 Mc

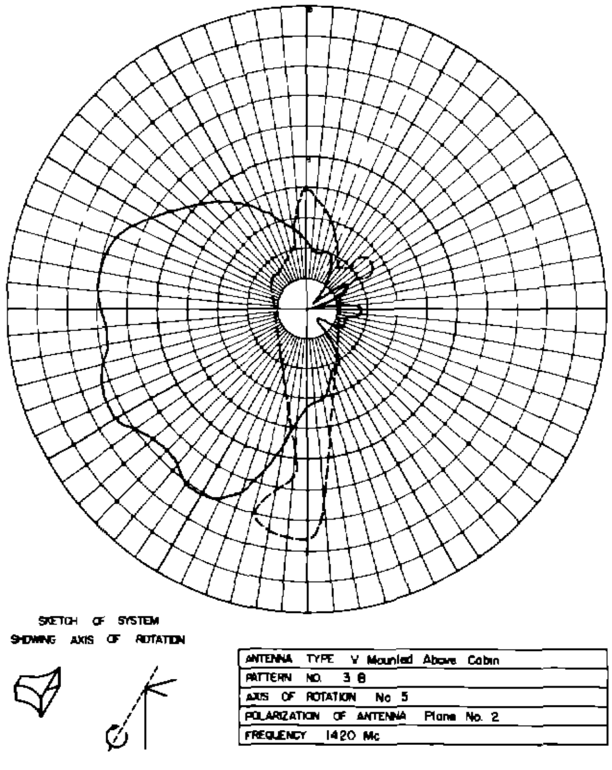


ANTENNA TYPE Free Space Of V Without Pedestal
PATTERN NO. 2 E
AXIS OF ROTATION No 4
POLARIZATION OF ANTENNA Plane No. 3 Cross
FREQUENCY 115 Mc

Fig 12 (Continued)







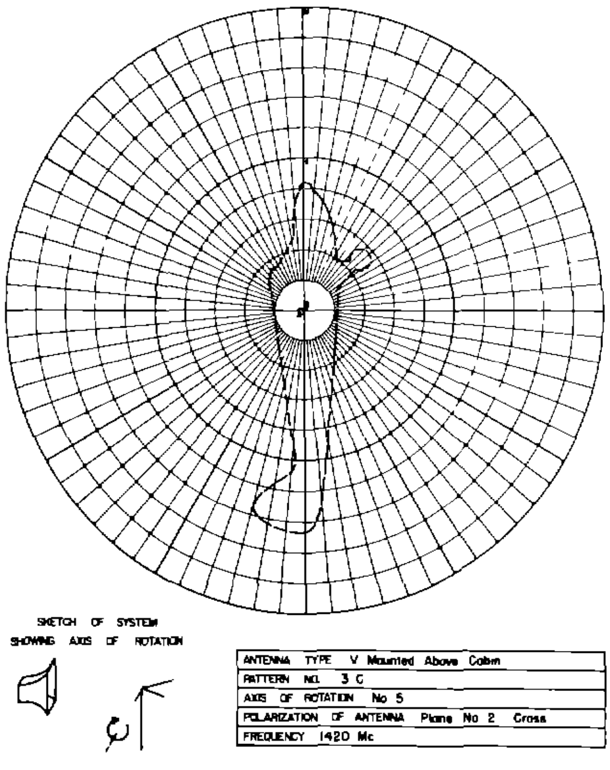
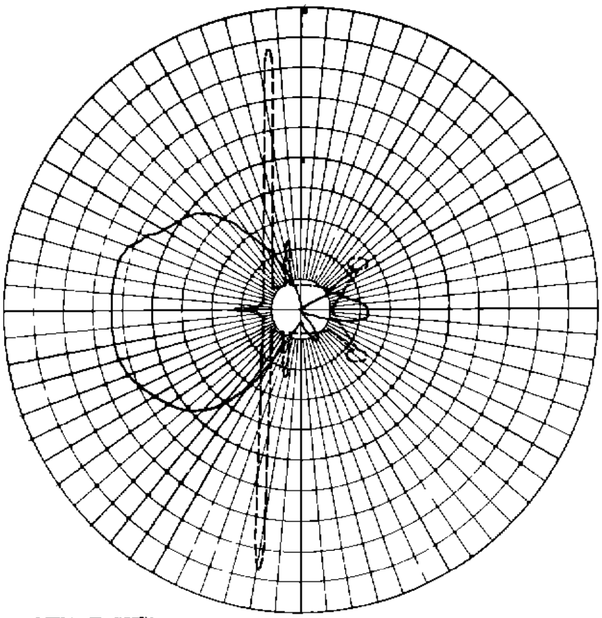
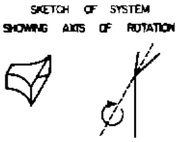
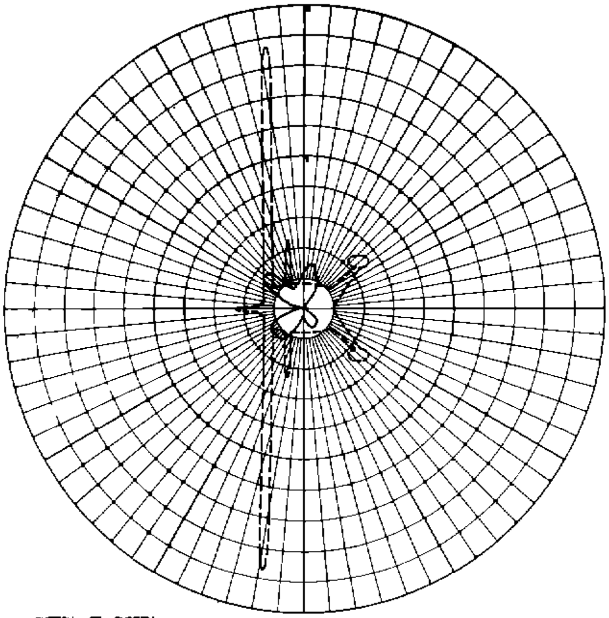


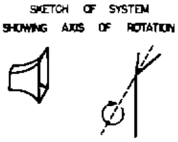
Fig 13 V-109 Antenna on Piper Cruiser Model at Location 3



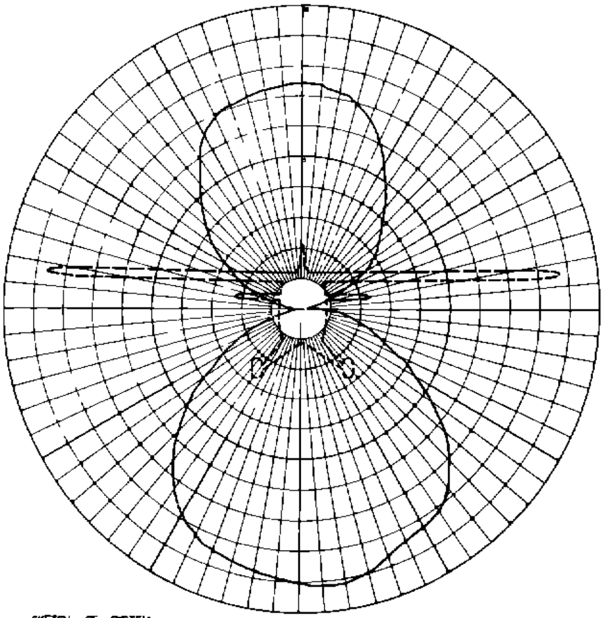


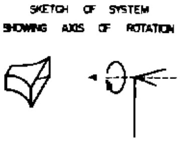
ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	3 D
AXIS OF ROTATION	No. 4
POLARIZATION OF ANTENNA	Plane No. 3
FREQUENCY	1420 Mc



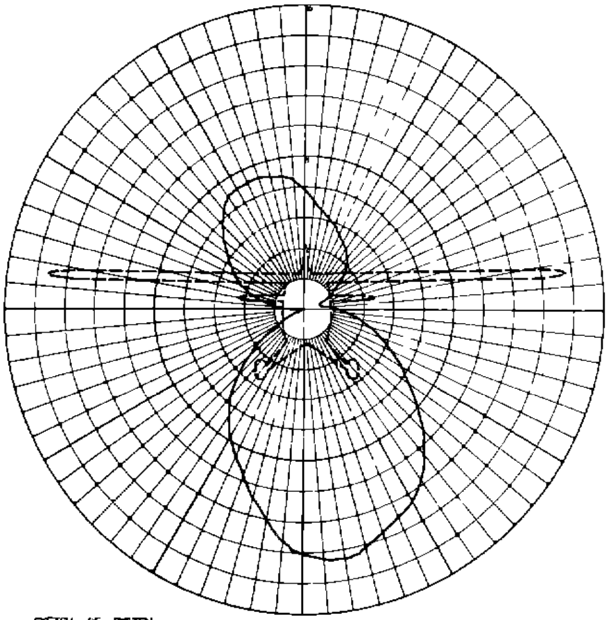


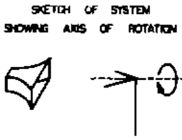
ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	3 E
AXIS OF ROTATION	No. 4
POLARIZATION OF ANTENNA	Plane No. 3 Cross
FREQUENCY	1420 Mc





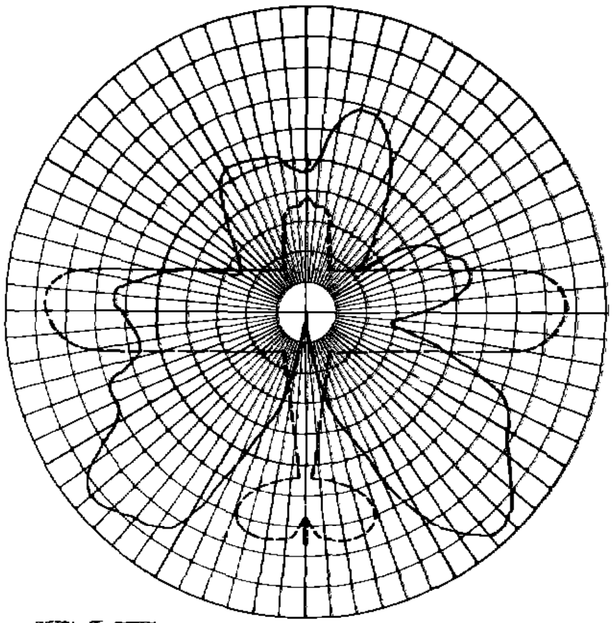
ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	3 F
AXIS OF ROTATION	No. 4 To
POLARIZATION OF ANTENNA	
FREQUENCY	1420 Mc

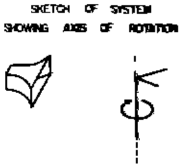




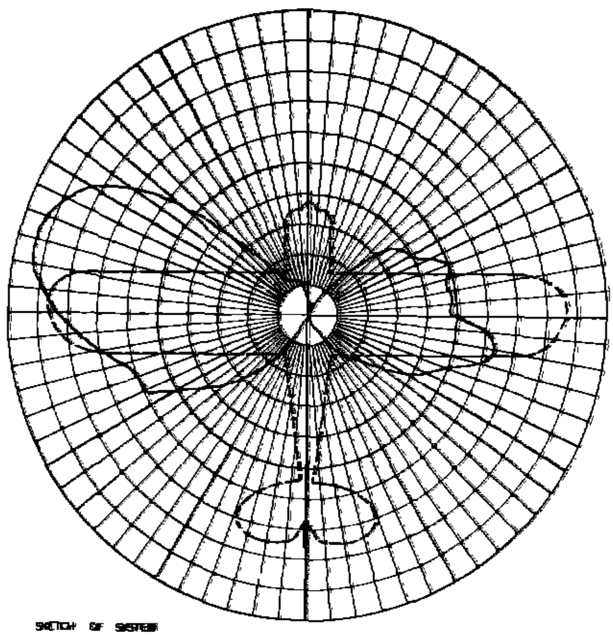
ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	3 G
AXIS OF ROTATION	No. 4 From
POLARIZATION OF ANTENNA	
FREQUENCY	1420 Mc

Fig 13 (Continued)

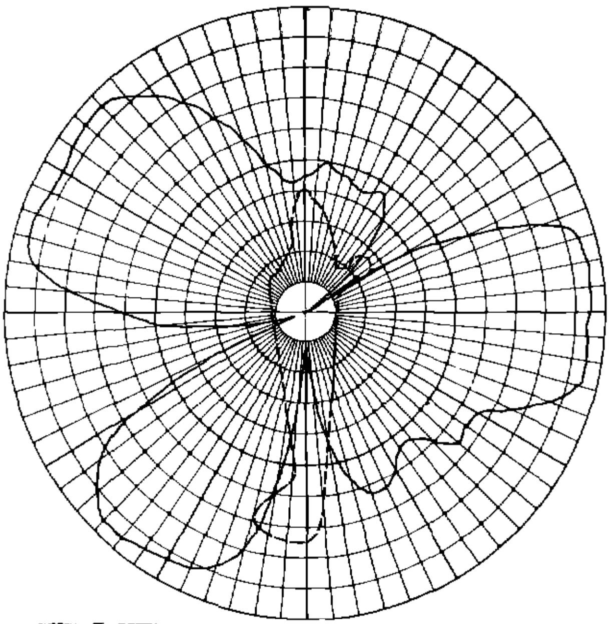


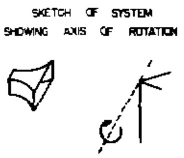


ANTENNA TYPE V Mounted Behind Cabin	
PATTERN NO. 4	
AXIS OF ROTATION No. 6	
POLARIZATION OF ANTENNA - Plane No. 1	
FREQUENCY - 1420 Mc	

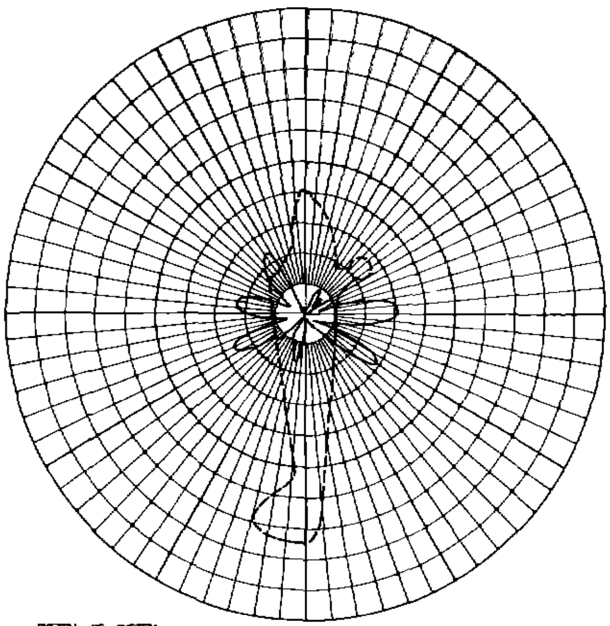


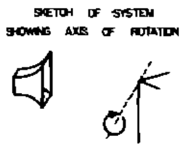
ANTENNA TYPE V Mounted Behind Cabin	
PATTERN NO. 4 A	
AXIS OF ROTATION - No. 6	
POLARIZATION OF ANTENNA - Plane No. 1 Cross	
FREQUENCY 1420 Mc.	





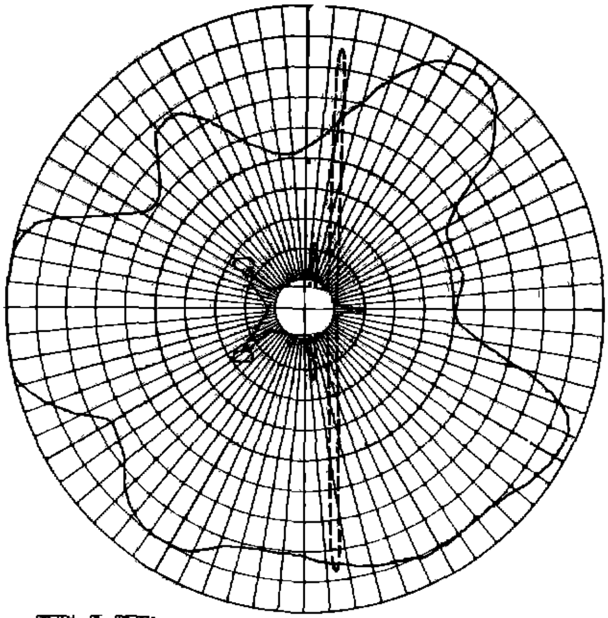
ANTENNA TYPE V Mounted Behind Cabin	
PATTERN NO. 4 B	
AXIS OF ROTATION No. 5	
POLARIZATION OF ANTENNA Plane No. 2	
FREQUENCY 1420 Mc	





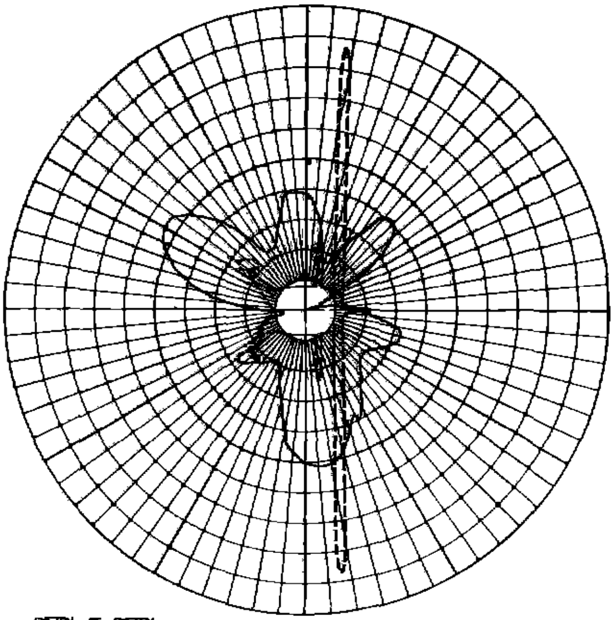
ANTENNA TYPE V Mounted Behind Cabin	
PATTERN NO. 4 C	
AXIS OF ROTATION No. 5	
POLARIZATION OF ANTENNA Plane No. 2 Cross	
FREQUENCY 1420 Mc	

Fig 14 V-109 Antenna on Piper Cruiser Model at Location 4



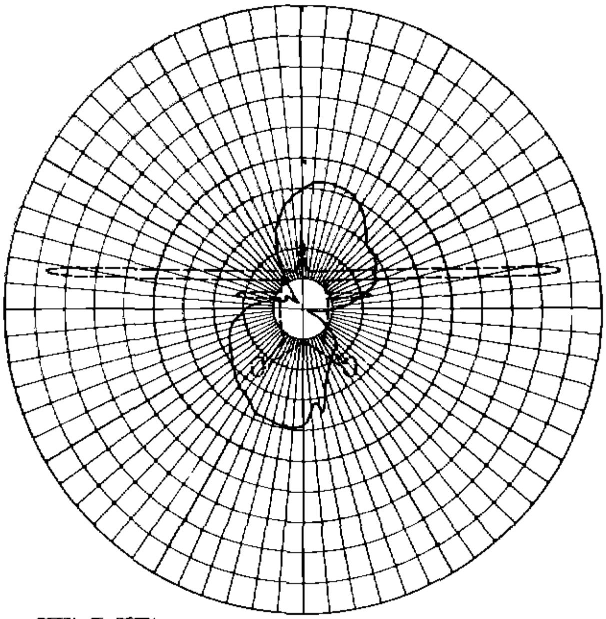
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE V Mounted Behind Cabin
PATTERN NO. 4[redacted]
AXIS OF ROTATION No. 4
POLARIZATION OF ANTENNA - Plane No. 3
FREQUENCY 1420 Mc

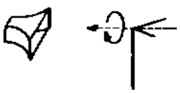


SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

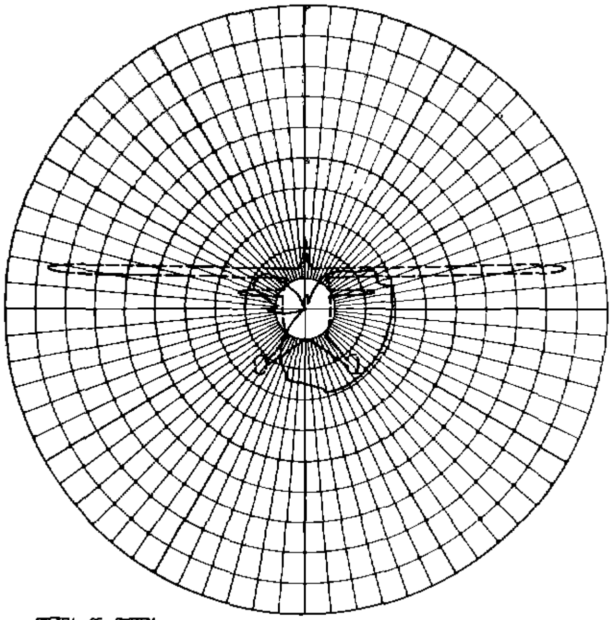
ANTENNA TYPE V Mounted Behind Cabin
PATTERN NO. 4 E
AXIS OF ROTATION No 4
POLARIZATION OF ANTENNA - Plane No. 3 Cross
FREQUENCY 1420 Mc.



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



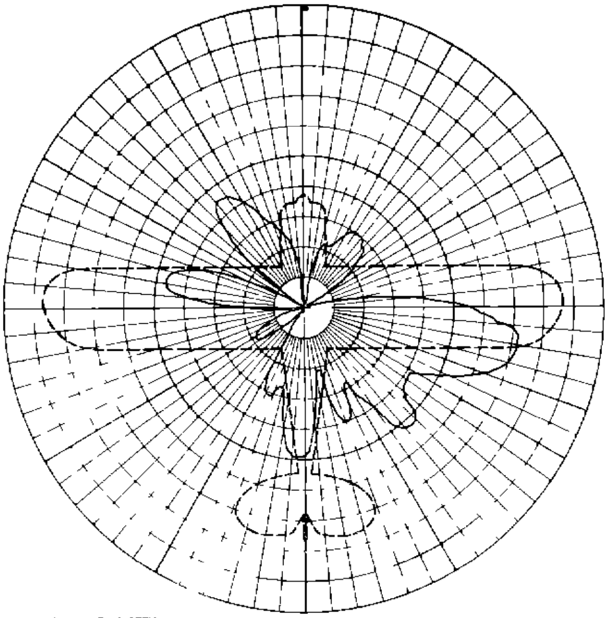
ANTENNA TYPE V Mounted Behind Cabin
PATTERN NO. 4[redacted]
AXIS OF ROTATION No 4 To
POLARIZATION OF ANTENNA
FREQUENCY 1420 Mc

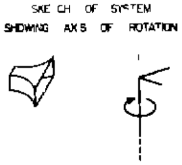


SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

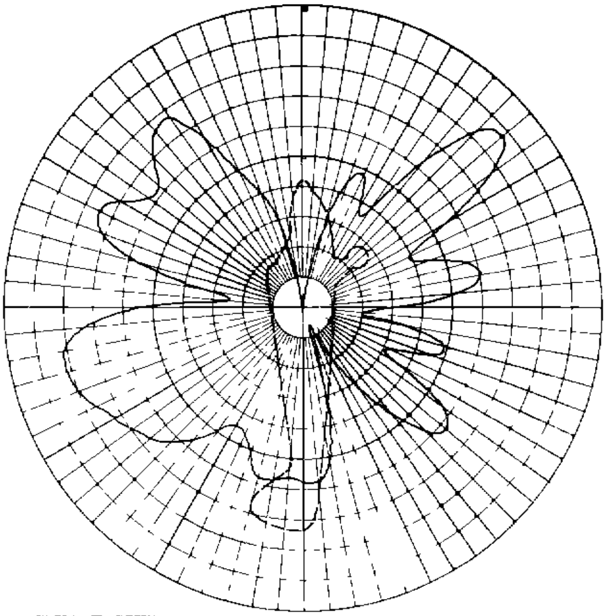
ANTENNA TYPE V Mounted Behind Cabin
PATTERN NO. 4[redacted]
AXIS OF ROTATION 4 From
POLARIZATION OF ANTENNA
FREQUENCY 1420 Mc.

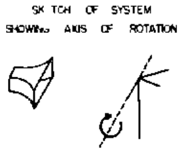
Fig 14 (Continued)



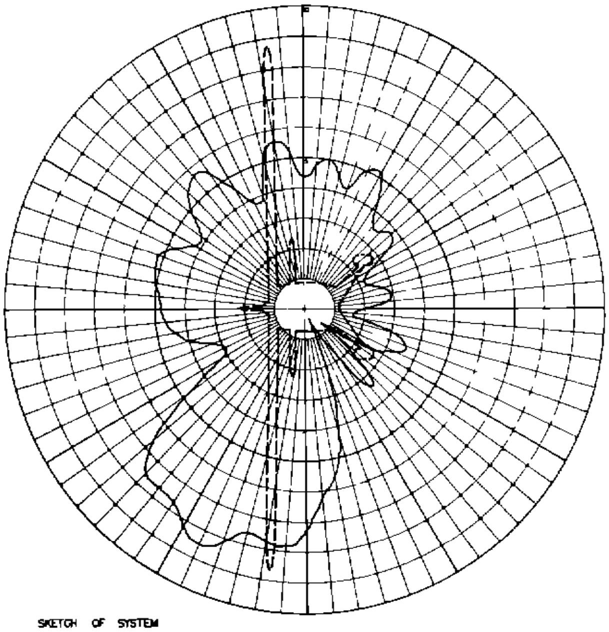


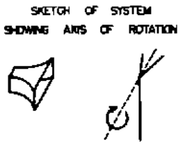
ANTENNA TYPE	V Mounted In Tail
PATTERN NO.	5
AXIS OF ROTATION	No 6
POLARIZATION OF ANTENNA	Plane No. I
FREQUENCY	1420 Mc





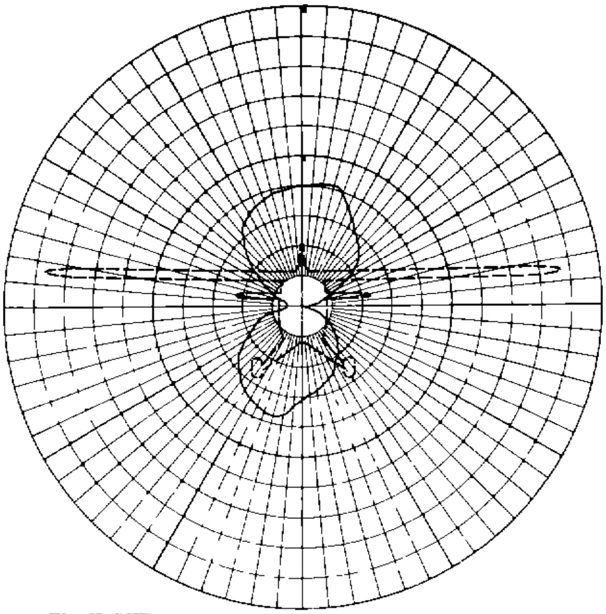
ANTENNA TYPE	V Mounted In Tail
PATTERN NO.	5 B
AXIS OF ROTATION	No 5
POLARIZATION OF ANTENNA	Plane No 2
FREQUENCY	1420 Mc



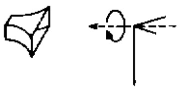


ANTENNA TYPE	V Mounted In Tail
PATTERN NO.	5 D
AXIS OF ROTATION	No. 4
POLARIZATION OF ANTENNA	Plane No. 3
FREQUENCY	1420 Mc

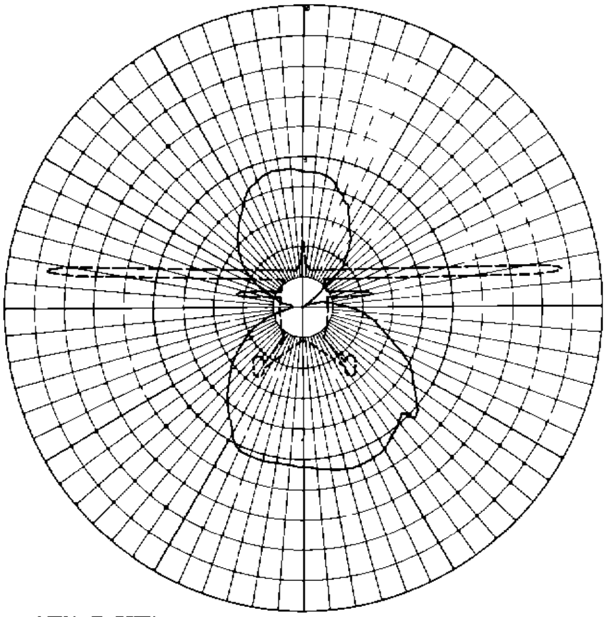
Fig 15 V-109 Antenna on Piper Cruiser Model at Location 5



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



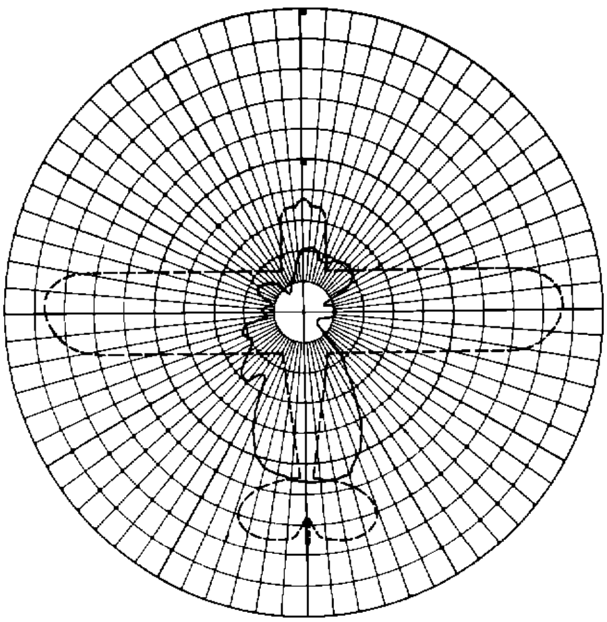
ANTENNA TYPE V Mounted in Tail
PATTERN NO. 5 F
AXIS OF ROTATION No 4 To
POLARIZATION OF ANTENNA
FREQUENCY 1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

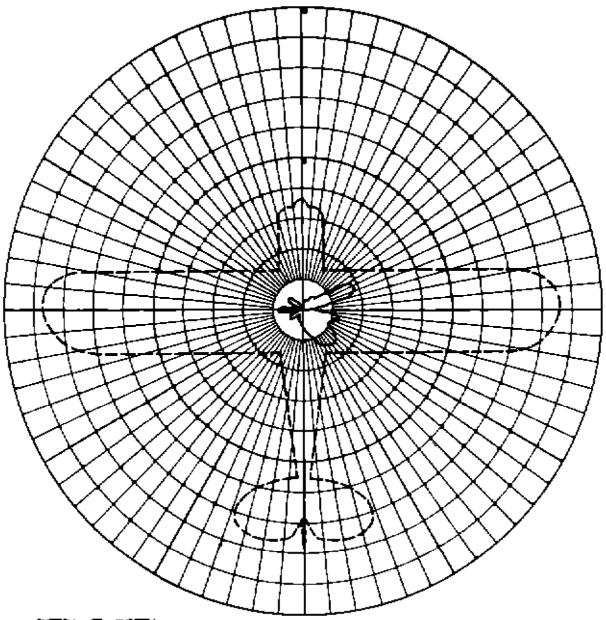
ANTENNA TYPE V Mountec In Tail
PATTERN NO 5 G
AXIS OF ROTATION No 4 From
POLARIZATION OF ANTENNA
FREQUENCY 1420 Mc

Fig 15 (Continued)



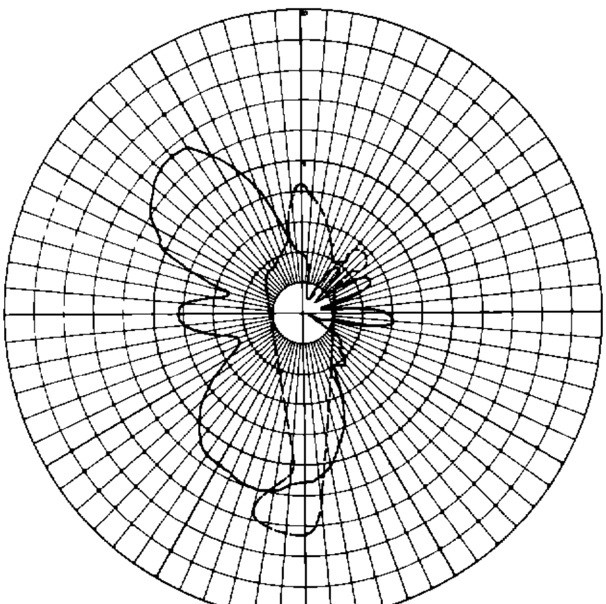
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE V Mounted Above Tail
PATTERN NO. 6
AXIS OF ROTATION No. 6
POLARIZATION OF ANTENNA Plane No. 1
FREQUENCY 1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

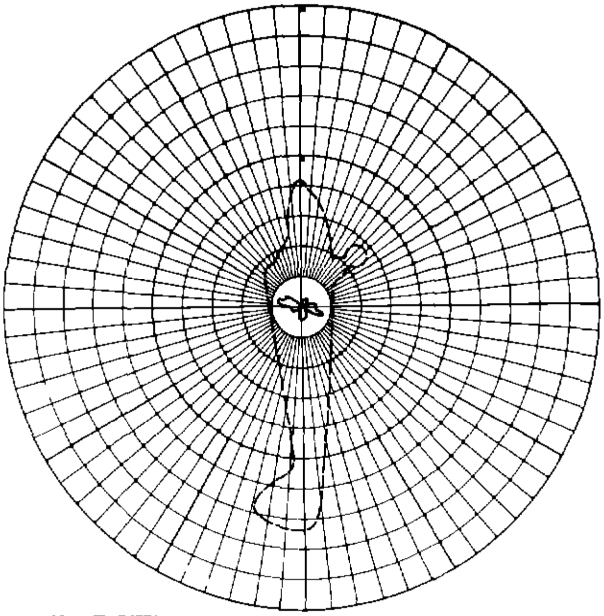
ANTENNA TYPE V Mounted Above Tail
PATTERN NO. 6 A
AXIS OF ROTATION No 6
POLARIZATION OF ANTENNA Plane No 1 Cross
FREQUENCY 1420 Mc.



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

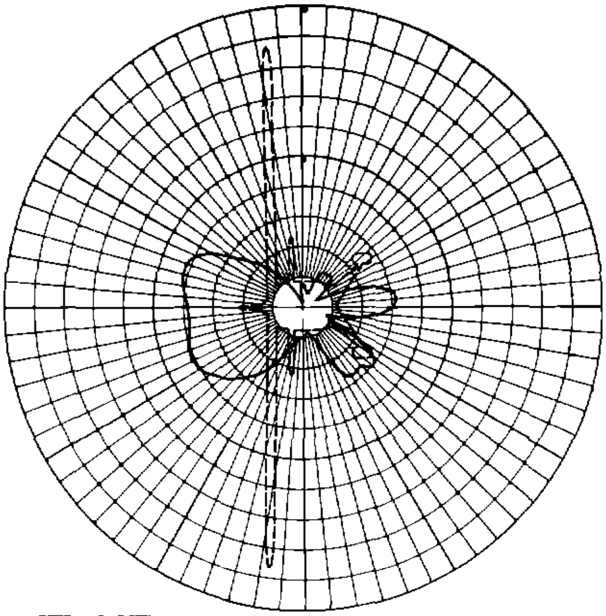
ANTENNA TYPE V Mounted Above Tail
PATTERN NO. 6 B
AXIS OF ROTATION No. 5
POLARIZATION OF ANTENNA Plane No 2
FREQUENCY 1420 Mc

Fig 16 V-109 Antenna on Piper Cruiser Model at Location 6



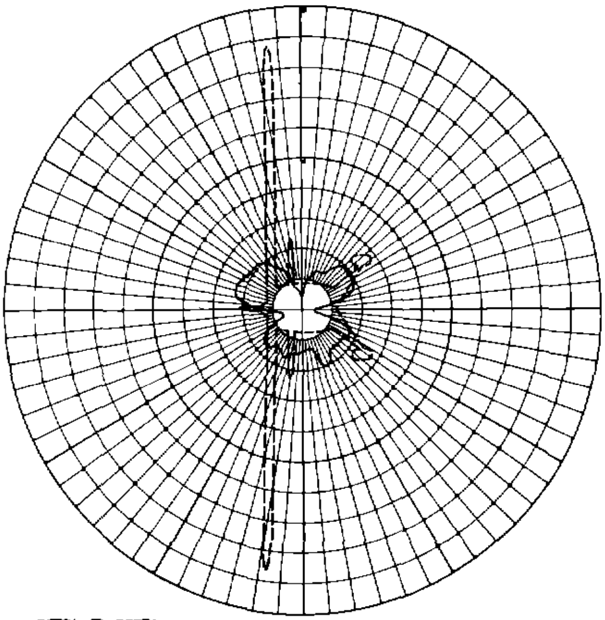
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE V Mounted Above Tail
PATTERN NO 6 C
AXIS OF ROTATION No. 5
POLARIZATION OF ANTENNA Plane No. 2 Cross
FREQUENCY 1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE V Mounted Above Tail
PATTERN NO 6 D
AXIS OF ROTATION No. 4
POLARIZATION OF ANTENNA Plane No 3
FREQUENCY 1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE V Mounted Above Tail
PATTERN NO. 6 E
AXIS OF ROTATION No. 4
POLARIZATION OF ANTENNA Plane No. 3 Cross
FREQUENCY 1420 Mc.

Fig 16 (Continued)

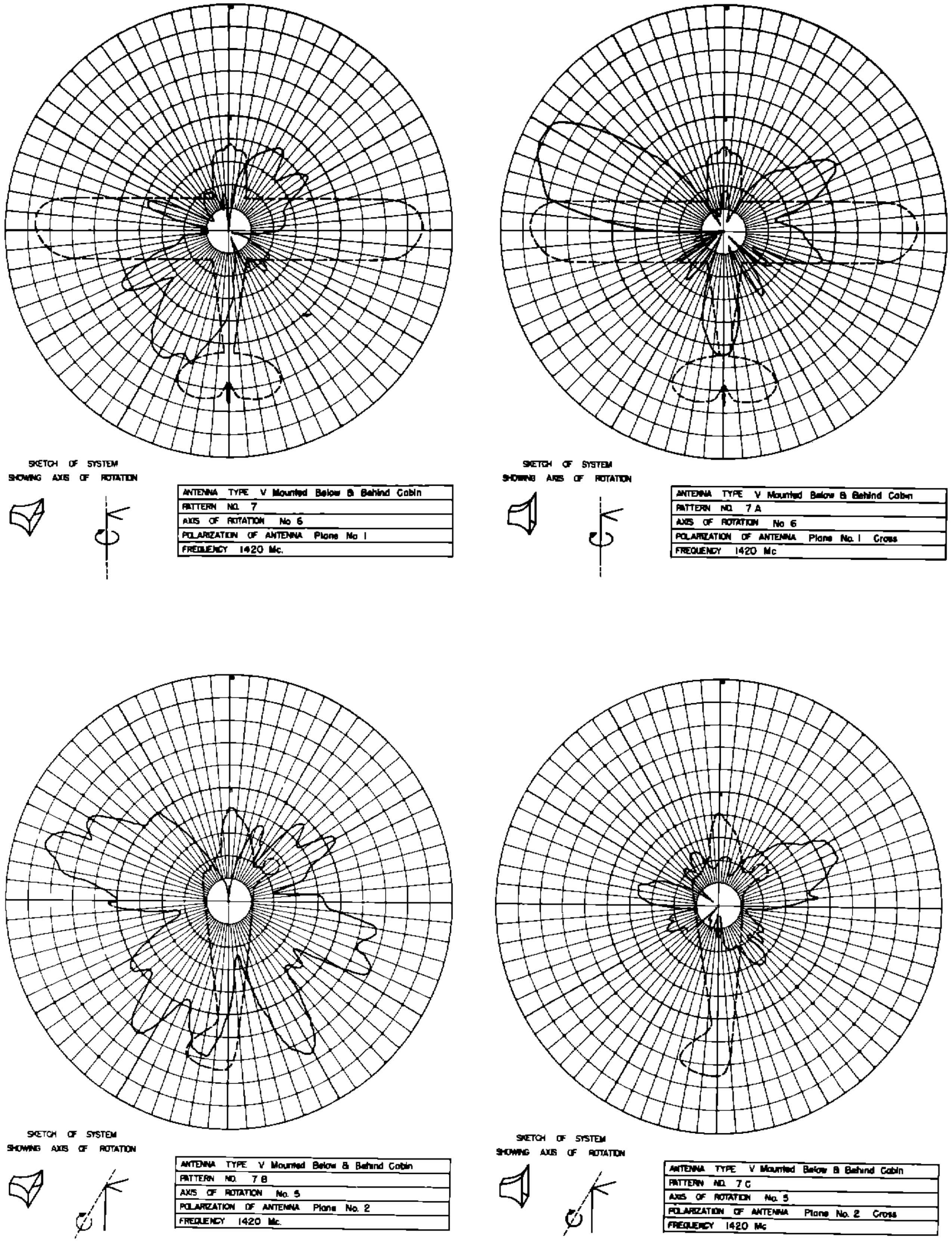
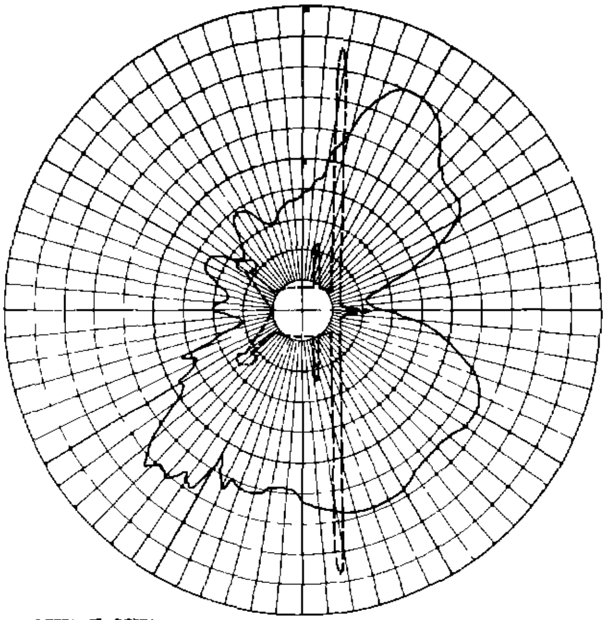
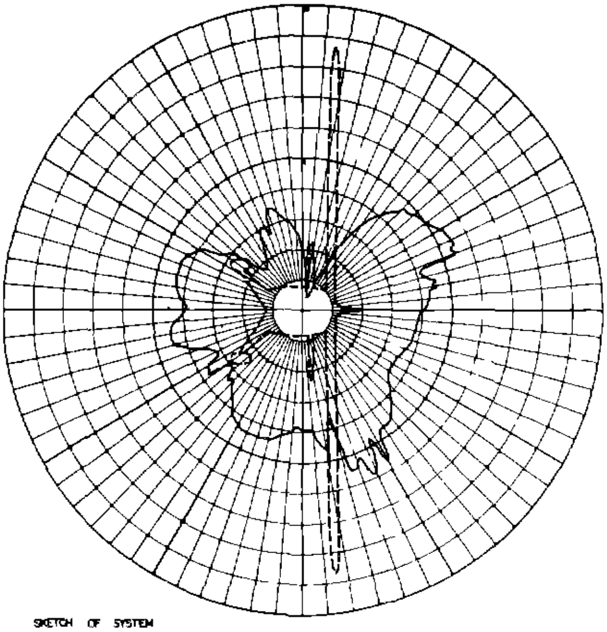


Fig 17 V-109 Antenna on Piper Cruiser Model at Location 7

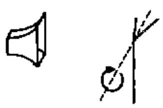


SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

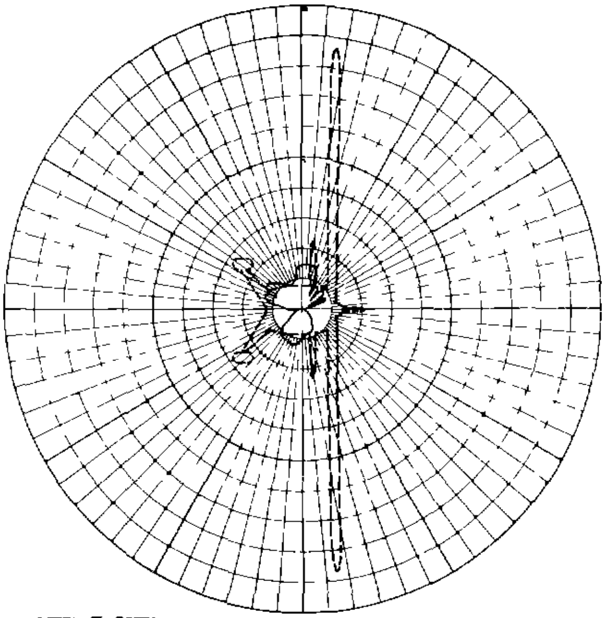
ANTENNA TYPE V Mounted Below & Behind Cabin
PATTERN NO. 7 D
AXIS OF ROTATION No. 4
POLARIZATION OF ANTENNA Plane No. 3
FREQUENCY 1420 Mc



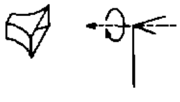
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



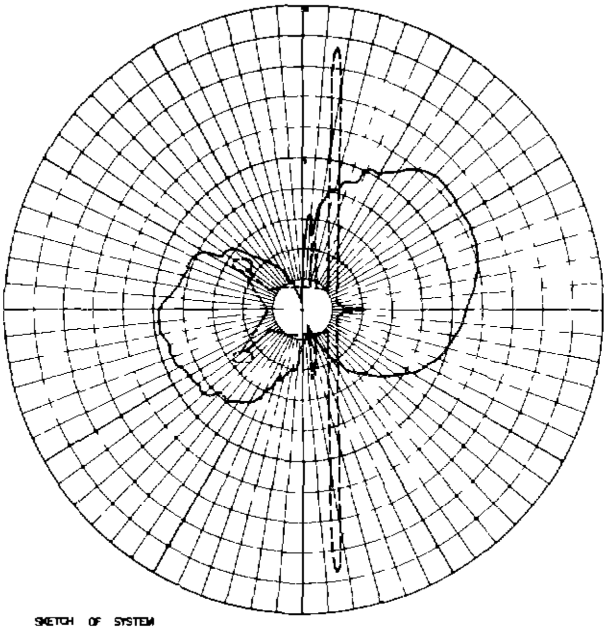
ANTENNA TYPE V Mounted Below & Behind Cabin
PATTERN NO 7 E
AXIS OF ROTATION No 4
POLARIZATION OF ANTENNA Plane No. 3 Cross
FREQUENCY 1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



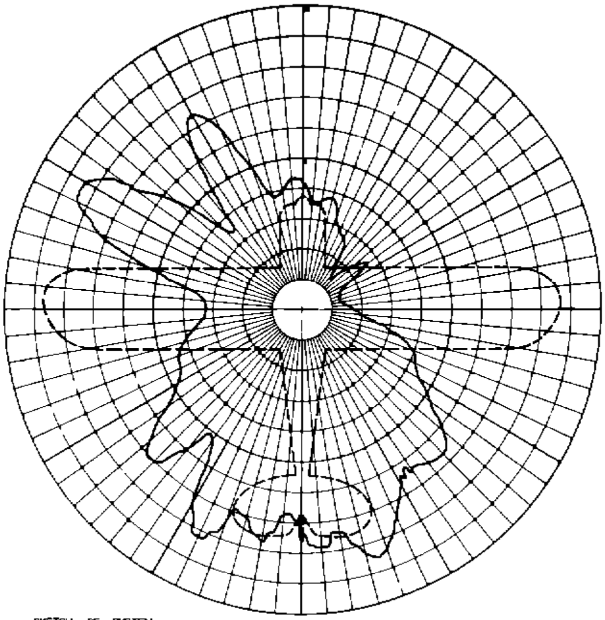
ANTENNA TYPE V Mounted Below & Behind Cabin
PATTERN NO. 7 F
AXIS OF ROTATION No 4 To
POLARIZATION OF ANTENNA
FREQUENCY 1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

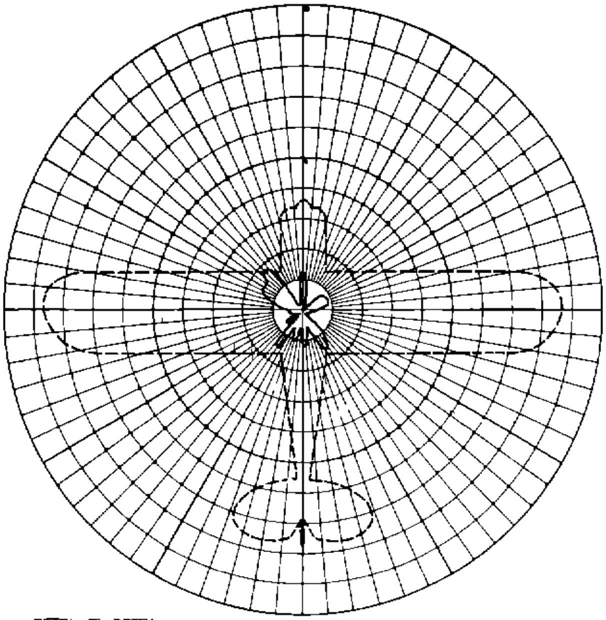
ANTENNA TYPE V Mounted Below & Behind Cabin
PATTERN NO. 7 G
AXIS OF ROTATION No 4 From
POLARIZATION OF ANTENNA
FREQUENCY 1420 Mc

Fig 17 (Continued)

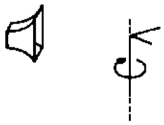


SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

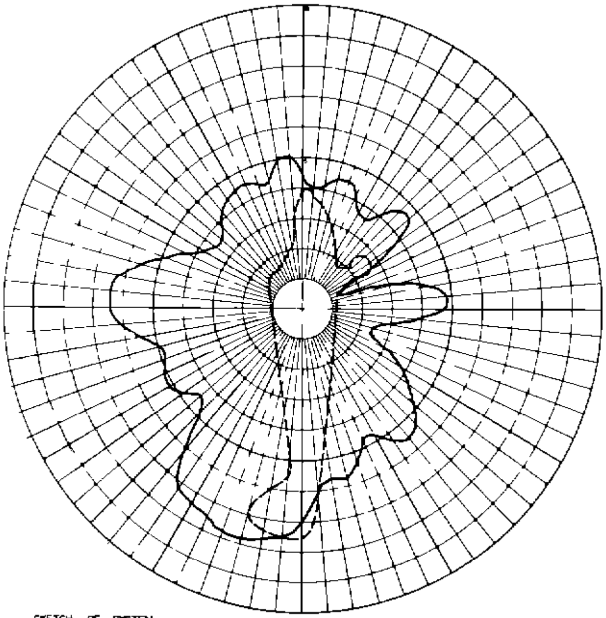
ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO.	8
AXIS OF ROTATION	No. 6
POLARIZATION OF ANTENNA	Plane No. 1
FREQUENCY	1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

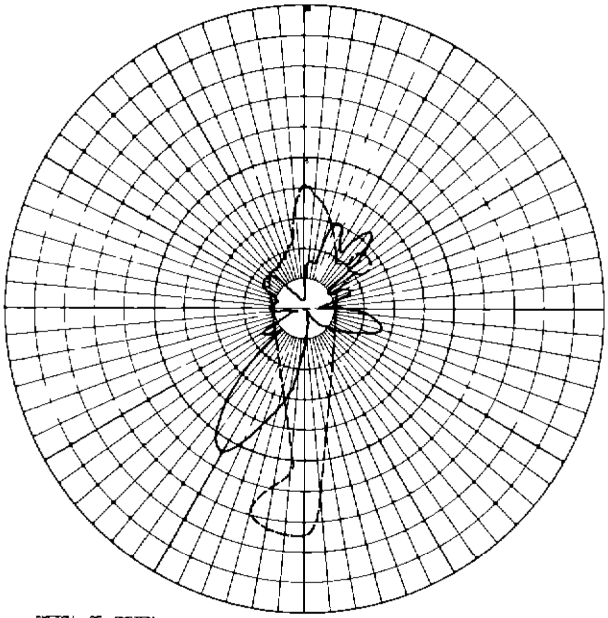


ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO	8 A
AXIS OF ROTATION	No 6
POLARIZATION OF ANTENNA	Plane No 1 Cross
FREQUENCY	1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

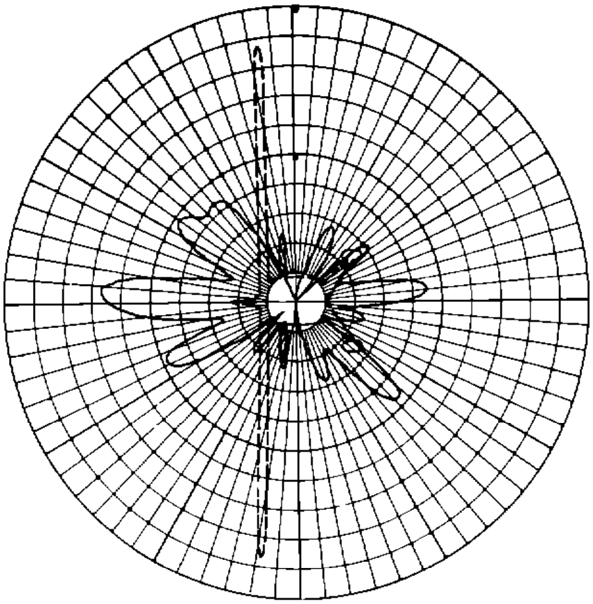
ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO.	8 B
AXIS OF ROTATION	No. 5
POLARIZATION OF ANTENNA	Plane No. 2
FREQUENCY	1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

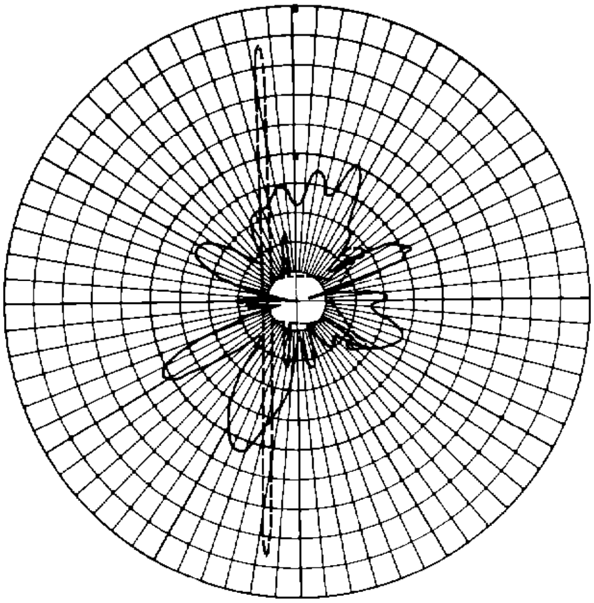
ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO	8 C
AXIS OF ROTATION	No. 5
POLARIZATION OF ANTENNA	Plane No. 2 Cross
FREQUENCY	1420 Mc

Fig 18 V-109 Antenna on Piper Cruiser Model at Location 8



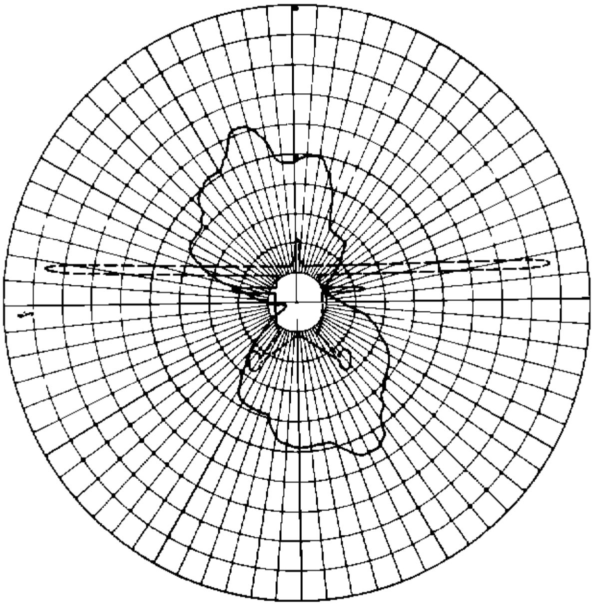
SKETCH OF SYSTEM SHOWING AXIS OF ROTATION

ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO.	8 D
AXIS OF ROTATION	No 4
POLARIZATION OF ANTENNA	Plane No 3
FREQUENCY	1420 Mc

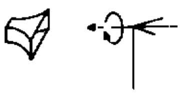


SKETCH OF SYSTEM SHOWING AXIS OF ROTATION

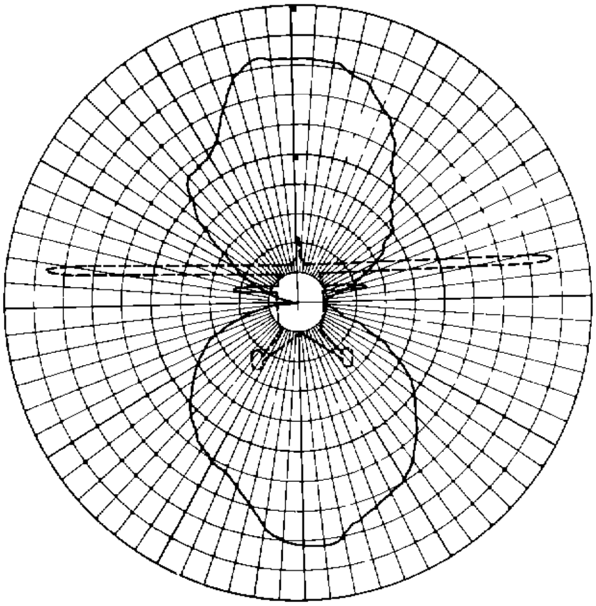
ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO.	8 E
AXIS OF ROTATION	No 4
POLARIZATION OF ANTENNA	Plane No. 3 Cross
FREQUENCY	1420 Mc



SKETCH OF SYSTEM SHOWING AXIS OF ROTATION



ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO.	8 F
AXIS OF ROTATION	No. 4 To
POLARIZATION OF ANTENNA	
FREQUENCY	1420 Mc



SKETCH OF SYSTEM SHOWING AXIS OF ROTATION

ANTENNA TYPE	V Mounted On Port Wing Tip
PATTERN NO.	8 G
AXIS OF ROTATION	No 4 From
POLARIZATION OF ANTENNA	
FREQUENCY	1420 Mc

Fig 18 (Continued)

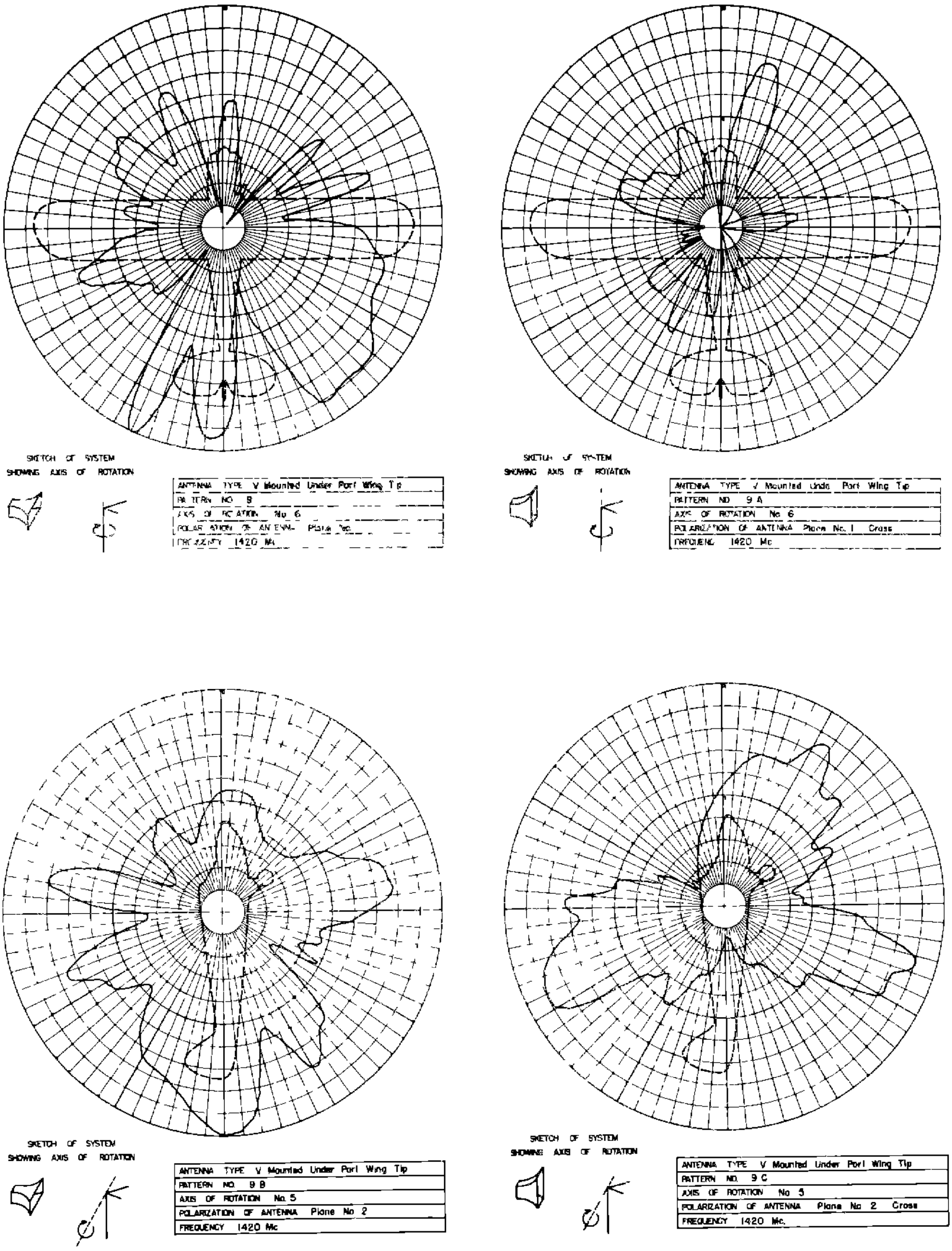
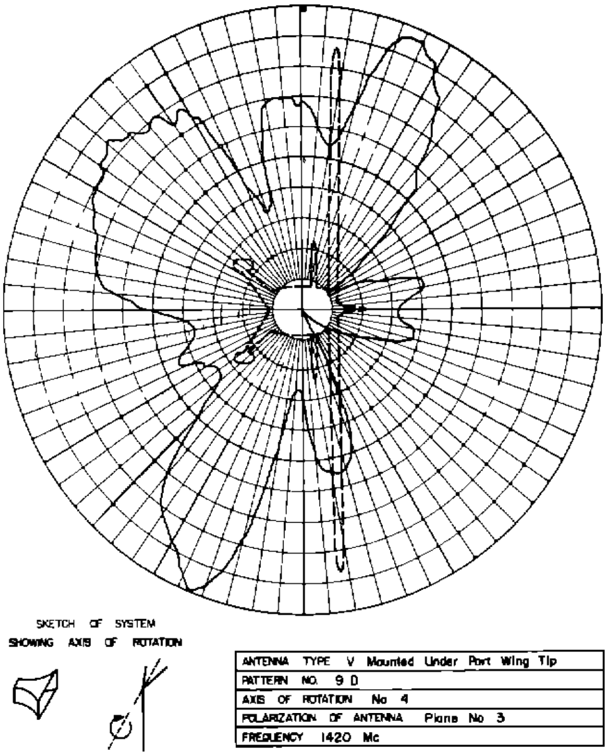
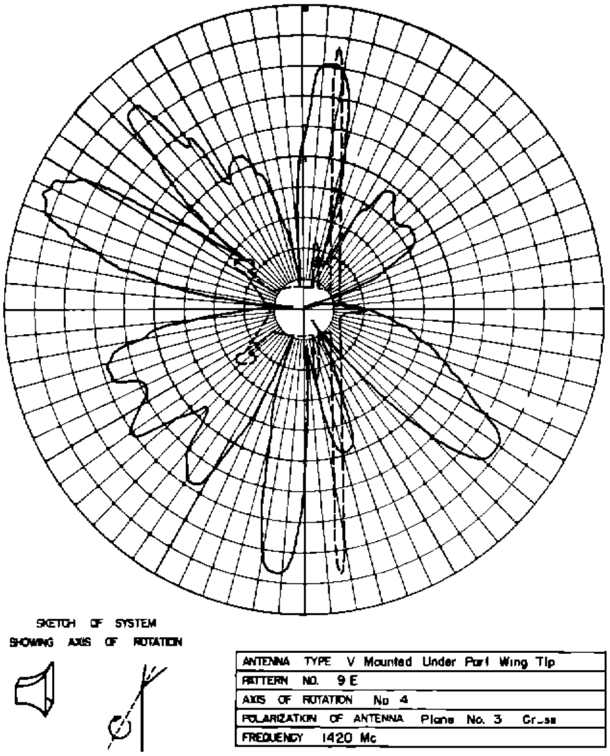
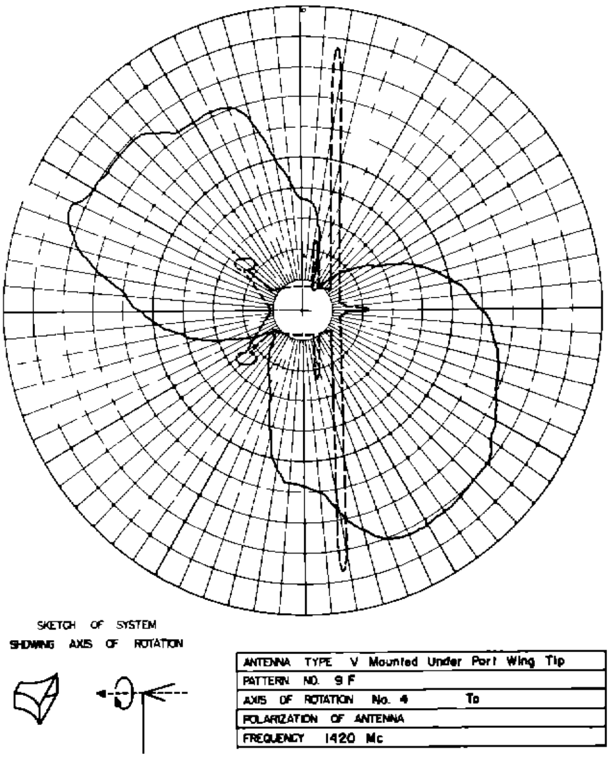


Fig 19 V-109 Antenna on Piper Cruiser Model at Location 9







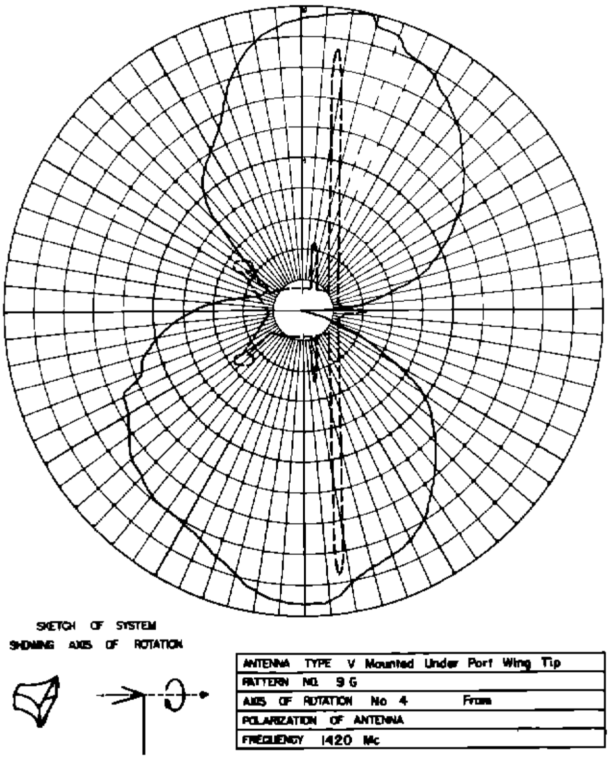


Fig 19 (Continued)

The patterns show that this location has some acceptable qualities Patterns 8 and 8A show that most of the pickup is directed rearward, and there are appreciable maxima in other directions The cross-polarization patterns are objectionably large The deep nulls in Pattern 8D are undesirable

V-109 Antenna on Piper Cruiser Model, Location 9

Fig 19 shows the results obtained with the V-109 antenna mounted on the lower surface of the Piper Cruiser wing (Location 9, Fig 9) at a point otherwise similar to Location 8

This location is probably unsatisfactory because of the abrupt variations in Pattern 9 and the large cross-polarization Patterns, 9A, 9C and 9E The placement of the nulls in Pattern 9F seems to indicate the presence of appreciable currents in the metal structure of the aircraft, causing sensitivity to cross-polarized signals

Shunt-Fed Wing-Tip Antenna on Piper Cruiser Model, Location 10

A shunt-fed quarter-wave stub antenna was mounted on the starboard wing tip of the Piper Cruiser model (Location 10, Fig 9) An installation of this kind on an actual aircraft is shown in the photographic view, Fig 20 The model range results obtained with this antenna are given in Fig 21

All patterns exhibit generally acceptable characteristics Pattern 10 and 10B show appreciable sensitivity fore and aft, and the downward portion of the vertical Pattern 10B leaves little to be desired Cross-polarized pickup, while appreciable, is usually smallest at angles where it is least desired, as shown in Patterns 10A, 10C and 10E

Series-Fed Wing-Tip Antenna on Piper Cruiser Model, Location 11

A series-fed quarter-wave stub antenna was next tried on the starboard wing tip of the Piper Cruiser model The installation was the same as that for the previous test except that the method of feed was changed

Fig 22 shows the pattern obtained As might be expected, the patterns for this antenna are very similar to those for the shunt-fed stub at the same location The series-fed installation is equally satisfactory

The Vertical Stabilizer Stub Antenna in the Piper Cruiser Model, Location 12

A shunt-fed vertical stub in the vertical stabilizer of the Piper Cruiser model was tested with a view towards its use as a VHF transmitting antenna The leading edge of the tail fin was isolated at the top and shunt fed at a point approximately a quarter wavelength below This is Location 12, Fig 9

The patterns obtained are given in Fig 23 Patterns 12 and 12A show undesirable nulls in the forward direction For this reason, this antenna location would probably be unsatisfactory

Conclusions

The model range tests on the Piper Cruiser indicate that the best location for the CAA V-109 antenna on this aircraft is above the fore part of the cabin on the center line, Location 3, Fig 9 Patterns of the V-109 antenna located on the vertical stabilizer indicate that this location is unsatisfactory on the Piper Cruiser, but that it might be acceptable on other types of aircraft with higher vertical stabilizers

Model tests show that good results might be obtained with a stub antenna mounted on the wing tip as shown in the photographic view, Fig 20 This antenna is also attractive from a mechanical standpoint in that it offers the possibility of a completely faired-in installation

METALLIZED MODEL STUDY

Technique

To check the performance of the V-109 antenna on metal covered aircraft, the framework of the Piper Cruiser model was covered with copper foil Pattern tests were then made on this metallized model

V-109 Antenna on Metallized Model, Location 13

Fig 24 shows the patterns obtained with the V-109 antenna mounted above the forward part of the cabin (Location 13, Fig 9) on the metallized Piper Cruiser model

Pattern 13 shows satisfactory signal pickup fore and aft although the greater sensitivity toward the rear is undesirable The pattern is not quite as good as that obtained with the fabric-covered model (Fig 13, Pattern 3).

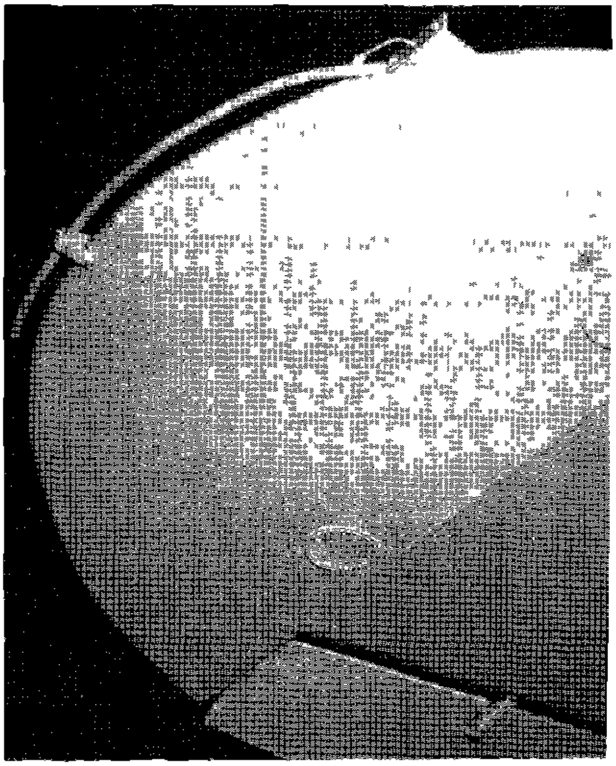


Fig 20 Wing-Tip Antenna on Piper Cruiser

Pattern 13B, while satisfactory, indicates that most of the signal pickup is in an upward direction as in Pattern 13D Compared to the fabric-covered model, Fig 13, Patterns 13B and 13D show the more complete shielding effect of the metal covering Cross-polarized components were negligible and for this reason Patterns 13A and 13C are not included

V-109 Antenna on Metallized Model Aircraft, Location 14

The V-109 antenna was moved approximately a quarter wavelength toward the rear of the aircraft, from Location 13 to Location 14, Fig 9 The pattern results obtained at this location are shown in Fig 25

Pattern 14 shows unsatisfactory characteristics in the forward direction, as does Pattern 14B Cross-polarized components are negligible The results are interesting, in that they show a considerable deterioration in performance with a relatively small change in antenna location

V-109 Antenna on Metallized Model Aircraft, Location 15

The V-109 antenna was moved another quarter wave toward the rear of the aircraft to Location 15, Fig 9 Fig 26 shows the patterns obtained

The low forward sensitivity indicated in Patterns 15 and 15B makes this location unsatisfactory Great improvement in downward pickup over that obtained at Location 14 is indicated in Pattern 15B

Series-Fed Wing-Tip Antenna on Metallized Model, Location 16

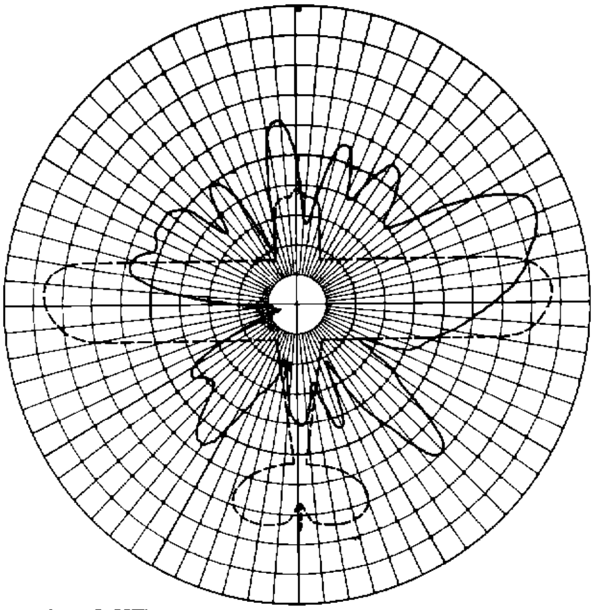
A series-fed stub antenna was installed on the starboard wing tip of the metallized model at Location 16, Fig 9 The model range patterns obtained are shown in Fig 27

Pattern 16 shows appreciable forward sensitivity, but with some undesirable variations Pattern 16B has excellent characteristics, although more sensitivity forward would be desirable The deep side nulls indicated in Patterns 16 and 16D are a serious disadvantage The patterns of Fig 27 closely resemble those for the fabric-skin model in Fig 22

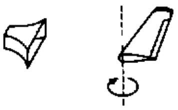
Metal Cylinder Tests

During preliminary experiments with the Piper Cruiser model and V-109 antenna it was observed that the forward sensitivity went through successive minima and maxima as the antenna was moved progressively backward on the center line of the aircraft To investigate this effect further, a model range experiment was set up in which the 1/12 size scale model of the V-109 antenna was used with a cylinder instead of the aircraft model The signal received by the antenna from the direction of the axis of the cylinder was measured as the position of the antenna was changed along that axis The diameter of the cylinder was 3 1/2 inches and the length 12 inches, corresponding to 0 24 and 1 44 wavelength respectively at the operating frequency of 1,420 Mc

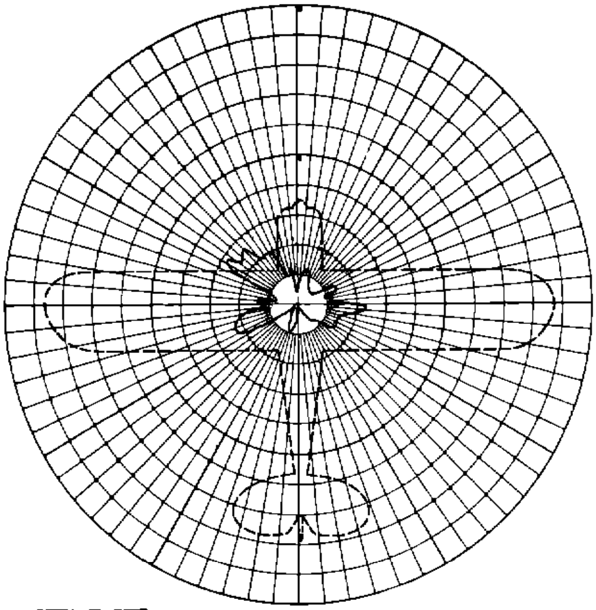
The results obtained are shown in the curve of Fig 28, which shows the received signal voltage as a function of antenna position along the longitudinal axis of the cylinder Examination of the curve reveals that similar points occur at intervals of multiples of a quarter wave, and that the first maximum is approximately a quarter wave from the end of the cylinder facing the signal source It probably can be concluded that, in the case of an antenna mounted on an actual aircraft,



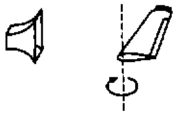
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



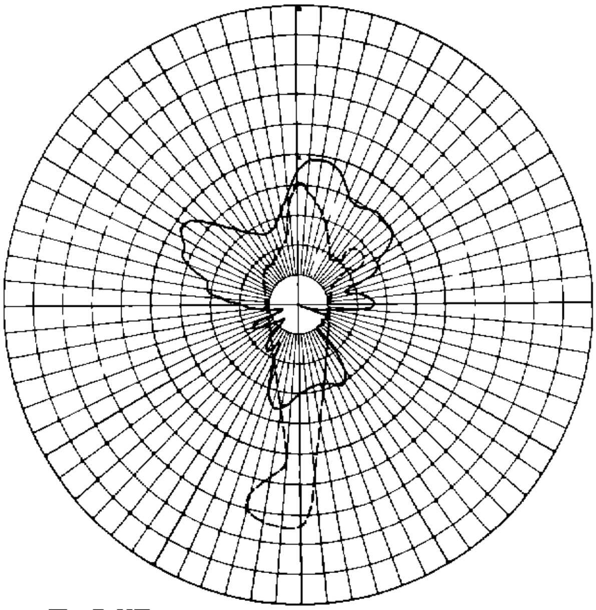
ANTENNA TYPE	Shunt Stub in Starboard Wing Tip
PATTERN NO.	10
AXIS OF ROTATION	No 6
POLARIZATION OF ANTENNA	Plane No. 1
FREQUENCY	1420 Mc



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

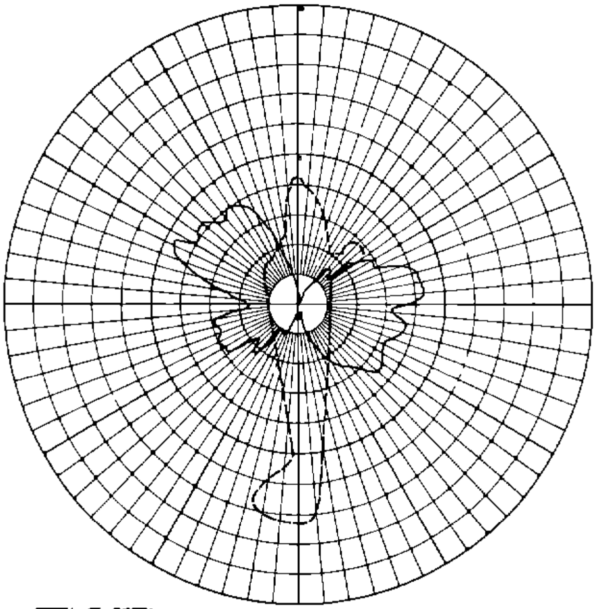


ANTENNA TYPE	Shunt Stub in Starboard Wing Tip
PATTERN NO.	10 A
AXIS OF ROTATION	No 6
POLARIZATION OF ANTENNA	Plane No. 1 Cross
FREQUENCY	1420 Mc.

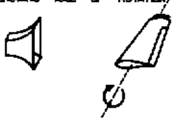


SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE	Shunt Stub in Starboard Wing Tip
PATTERN NO.	10 B
AXIS OF ROTATION	No. 5
POLARIZATION OF ANTENNA	Plane No. 2
FREQUENCY	1420 Mc

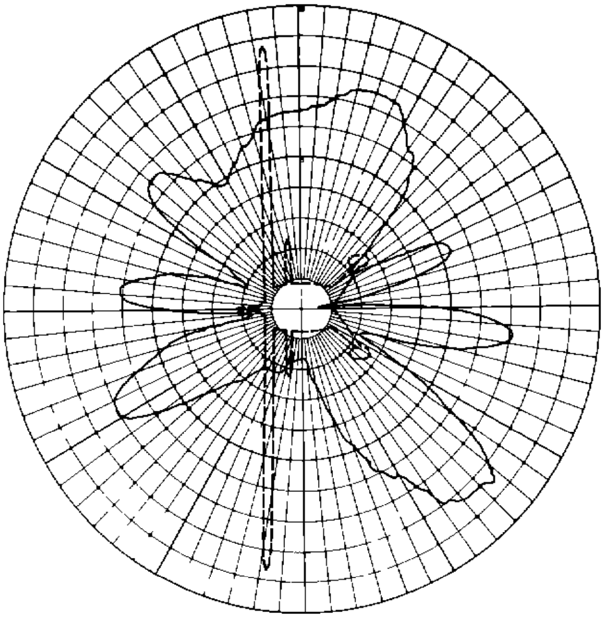


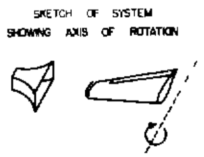
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



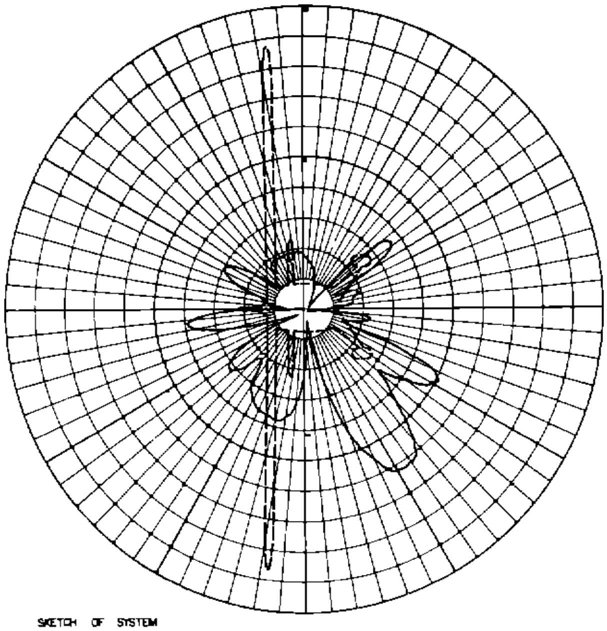
ANTENNA TYPE	Shunt Stub in Starboard Wing Tip
PATTERN NO.	10 C
AXIS OF ROTATION	No. 5
POLARIZATION OF ANTENNA	Plane No 2 Cross
FREQUENCY	1420 Mc.

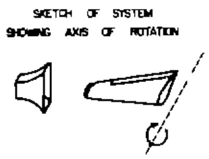
Fig 21 Shunt-Fed Wing-Tip Antenna on Piper Cruiser Model at Location 10



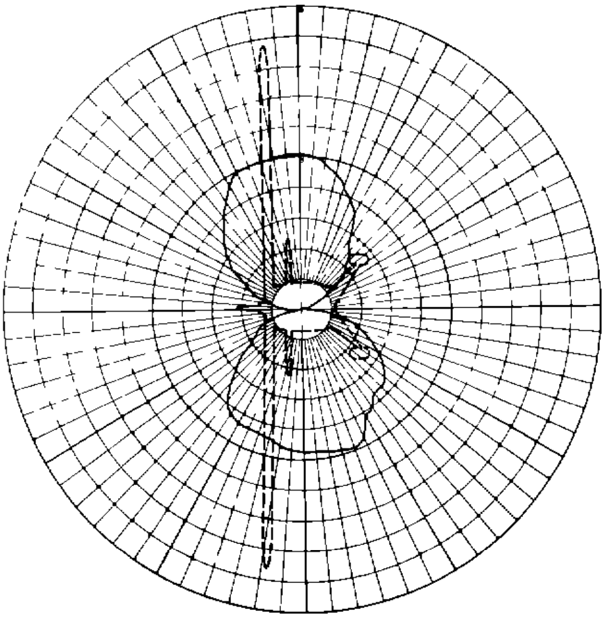


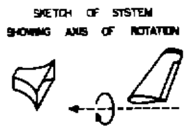
ANTENNA TYPE	Shunt Stub In Starboard Wing Tip
PATTERN NO.	10 D
AXIS OF ROTATION	No 4
POLARIZATION OF ANTENNA	Plane No. 3
FREQUENCY	1420 Mc



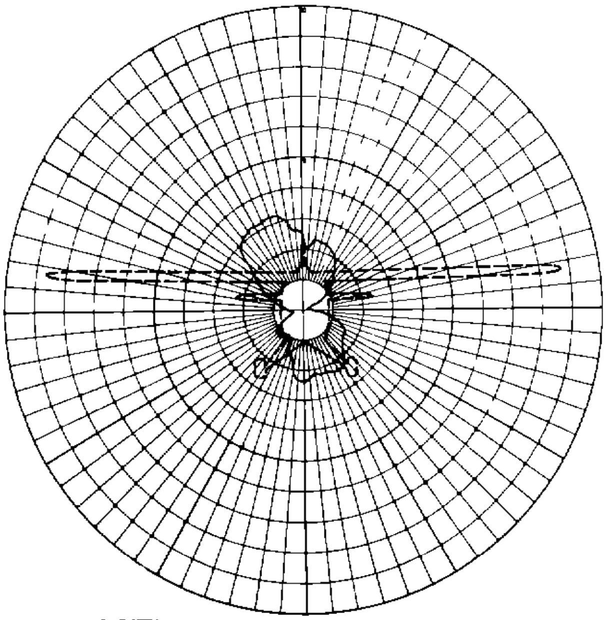


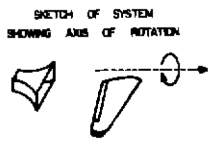
ANTENNA TYPE	Shunt Stub In Starboard Wing Tip
PATTERN NO.	10 E
AXIS OF ROTATION	No 4
POLARIZATION OF ANTENNA	Plane No 3 Cross
FREQUENCY	1420 Mc





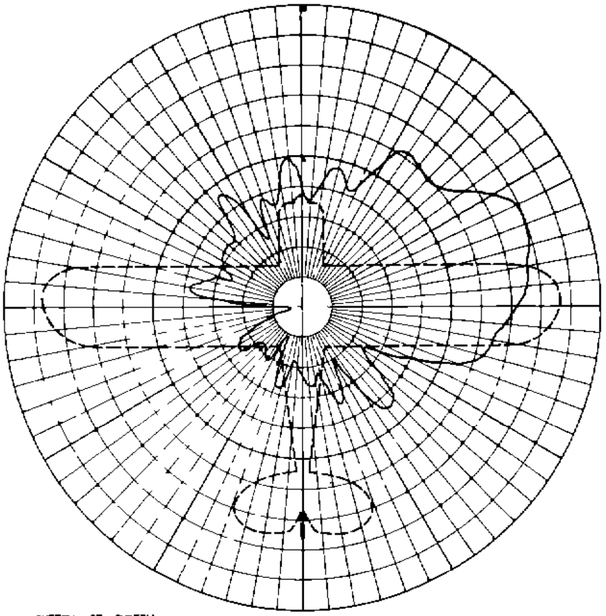
ANTENNA TYPE	Shunt Stub In Starboard Wing Tip
PATTERN NO.	10 F
AXIS OF ROTATION	No 4 To
POLARIZATION OF ANTENNA	
FREQUENCY	1420 Mc.

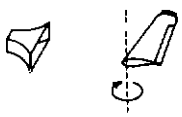




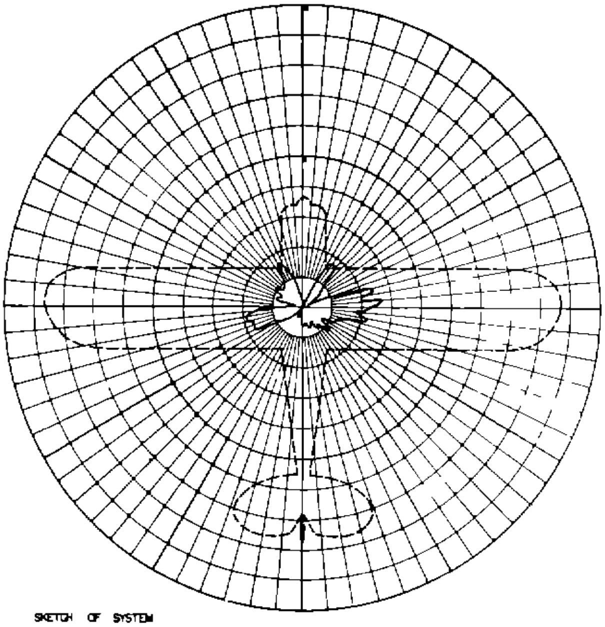
ANTENNA TYPE	Shunt Stub In Starboard Wing Tip
PATTERN NO.	10 G
AXIS OF ROTATION	No. 4 From
POLARIZATION OF ANTENNA	
FREQUENCY	1420 Mc.

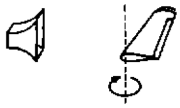
Fig 21 (Continued)



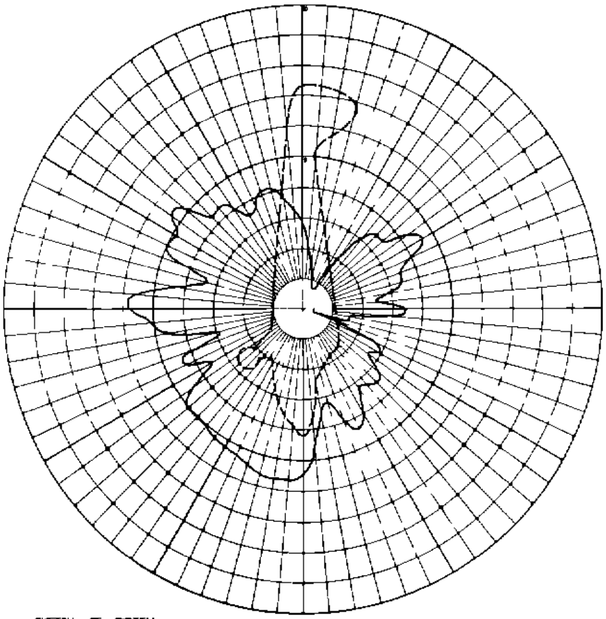


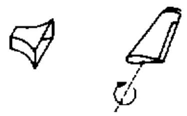
ANTENNA TYPE Series Stub in Starboard Wing Tip	
PATTERN NO. 11	
AXIS OF ROTATION No 6	
POLARIZATION OF ANTENNA Plane No 1	
FREQUENCY 1420 Mc	



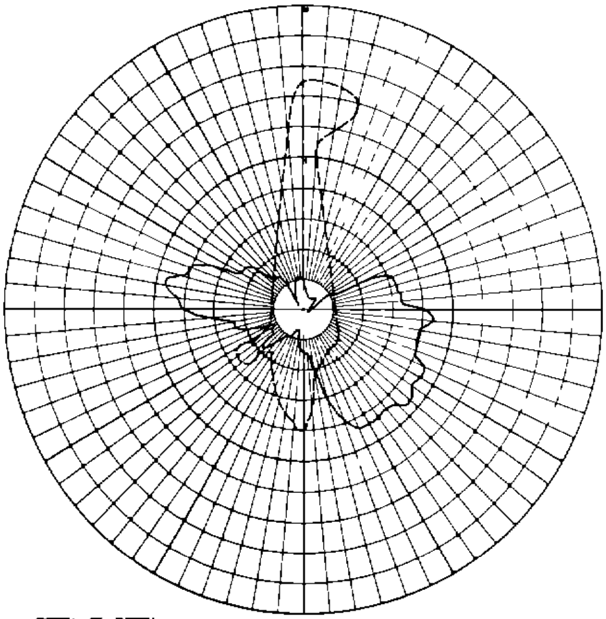


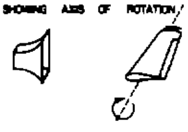
ANTENNA TYPE Series Stub in Starboard Wing Tip	
PATTERN NO 11 A	
AXIS OF ROTATION	
POLARIZATION OF ANTENNA Plane No 1 Cross	
FREQUENCY 1420 Mc	





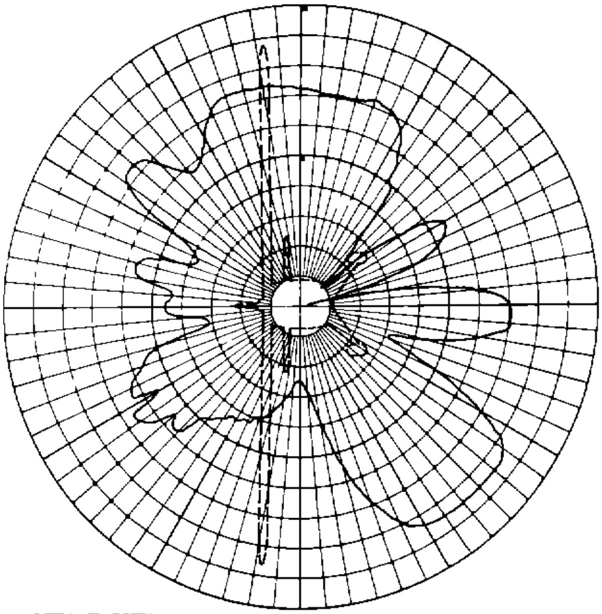
ANTENNA TYPE Series Stub in Starboard Wing Tip	
PATTERN NO. 11 B	
AXIS OF ROTATION No 5	
POLARIZATION OF ANTENNA Plane No 2	
FREQUENCY 1420 Mc	



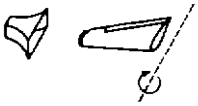


ANTENNA TYPE Series Stub in Starboard Wing Tip	
PATTERN NO. 11 C	
AXIS OF ROTATION No. 5	
POLARIZATION OF ANTENNA Plane No 2 Cross	
FREQUENCY 1420 Mc	

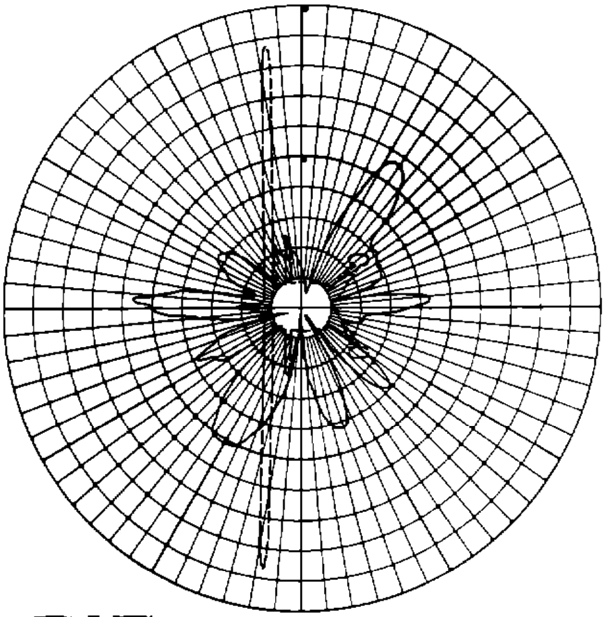
Fig 22 Series-Fed Wing-Tip Antenna on Piper Cruiser Model at Location 11



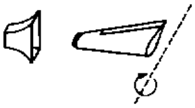
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



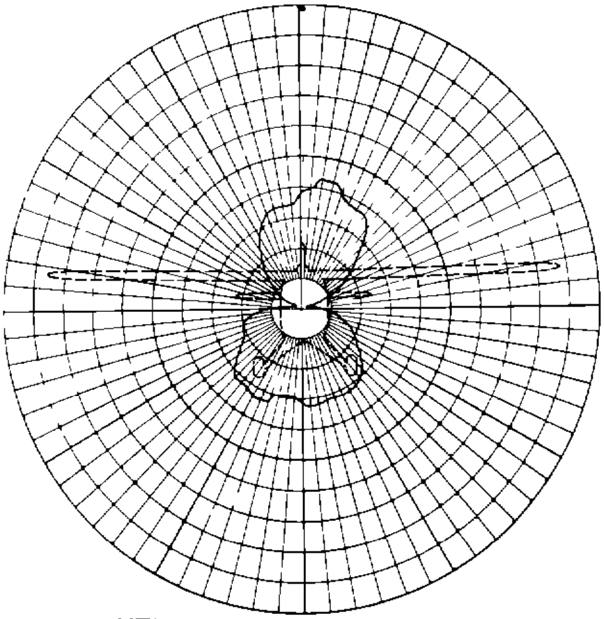
ANTENNA TYPE Series Stub In Starboard Wing Tip	
PATTERN NO. 11 D	
AXIS OF ROTATION No 4	
POLARIZATION OF ANTENNA Plane No 3	
FREQUENCY 1420 Mc	



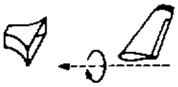
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



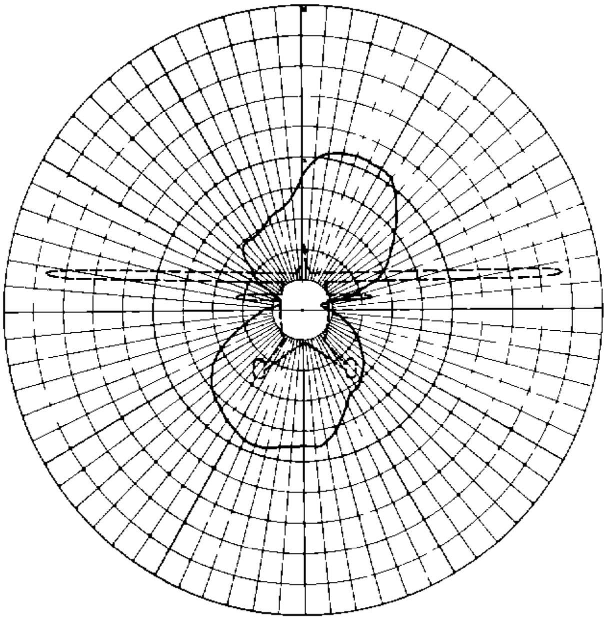
ANTENNA TYPE Series Stub In Starboard Wing Tip	
PATTERN NO. 11 E	
AXIS OF ROTATION No 4	
POLARIZATION OF ANTENNA Plane No. 3	Cross
FREQUENCY 1420 Mc	



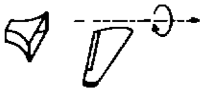
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



ANTENNA TYPE Series Stub In Starboard Wing Tip	
PATTERN NO. 11 F	
AXIS OF ROTATION No 4	To
POLARIZATION OF ANTENNA	
FREQUENCY 1420 Mc	

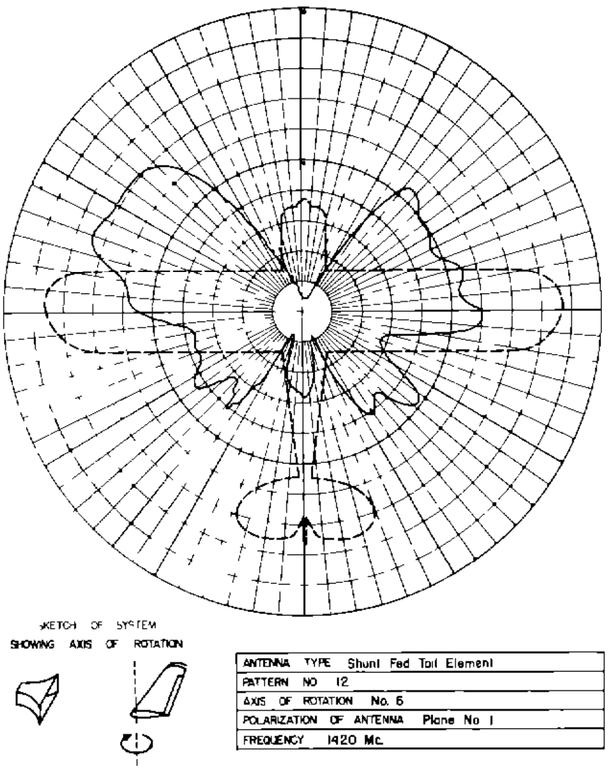


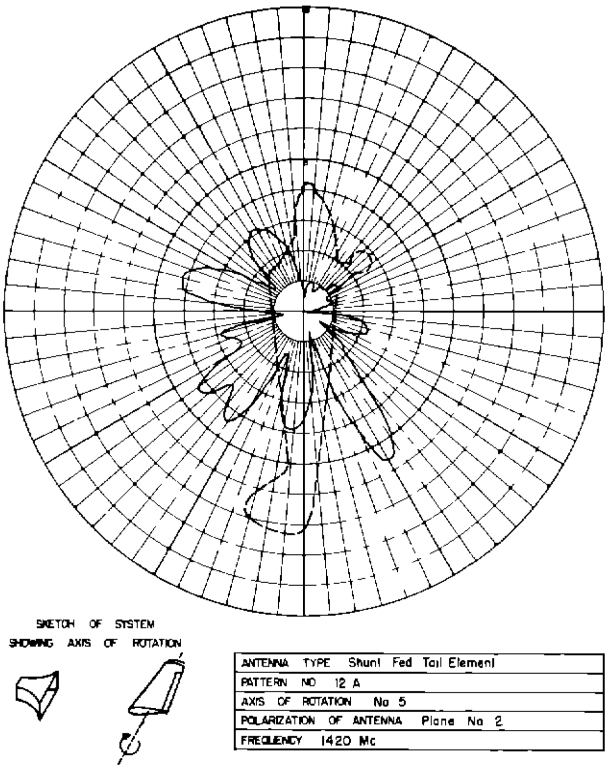
SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



ANTENNA TYPE Series Stub In Starboard Wing Tip	
PATTERN NO. 11 G	
AXIS OF ROTATION No 4	From
POLARIZATION OF ANTENNA	
FREQUENCY 1420 Mc.	

Fig 22 (Continued)





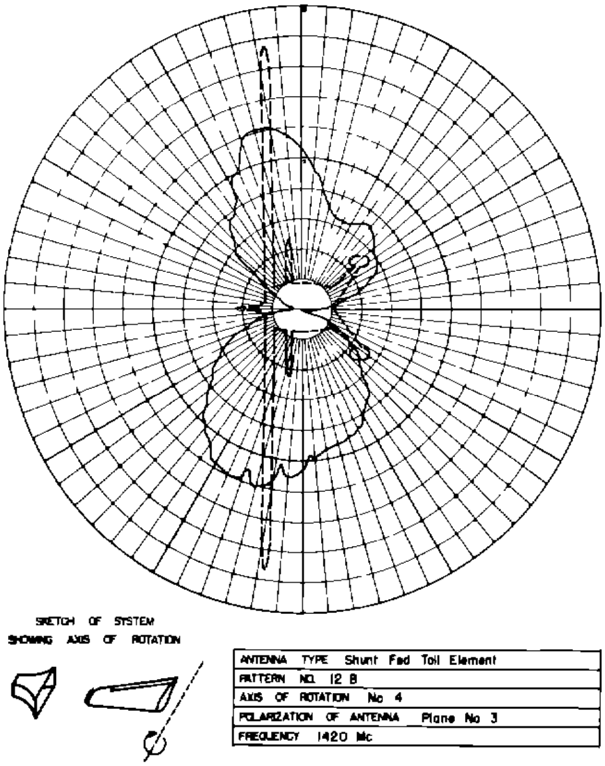
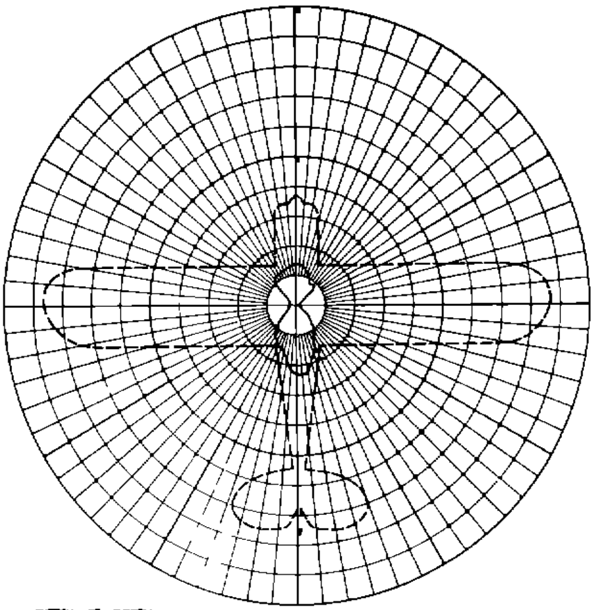
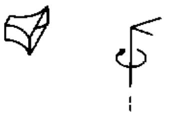


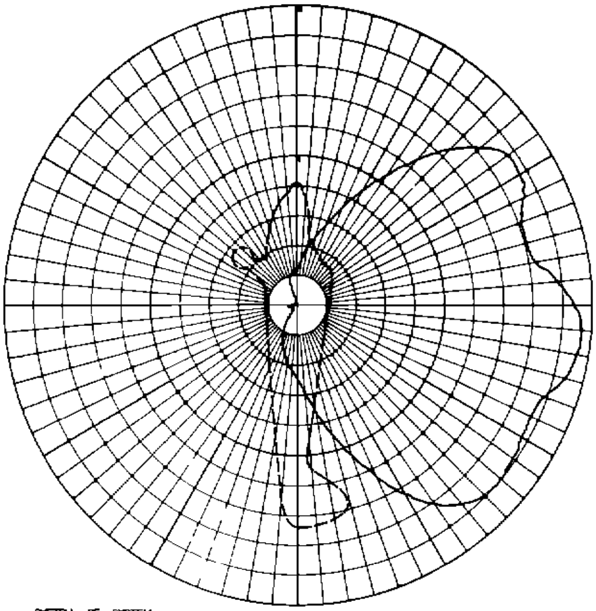
Fig 23 Shunt-Fed Vertical Stabilizer Stub Antenna on Piper Cruiser Model at Location 12



SKETCH OF SYSTEM SHOWING AXIS OF ROTATION

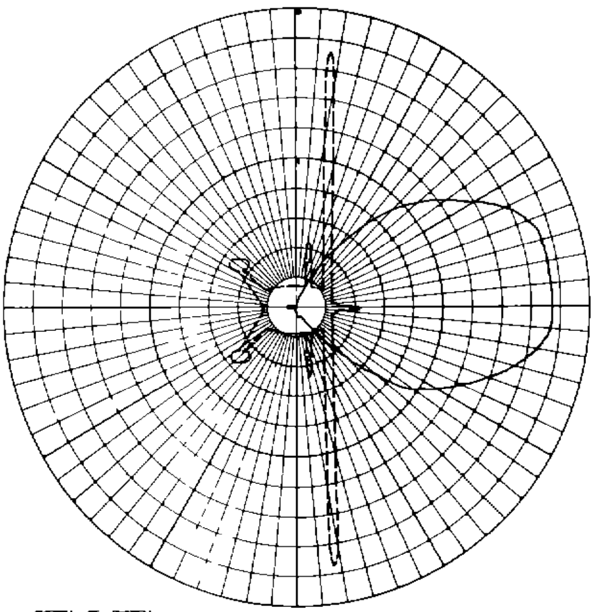


ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	13
AXIS OF ROTATION	No. 6
POLARIZATION OF ANTENNA	Plane No. 1
FREQUENCY	1420 Mc



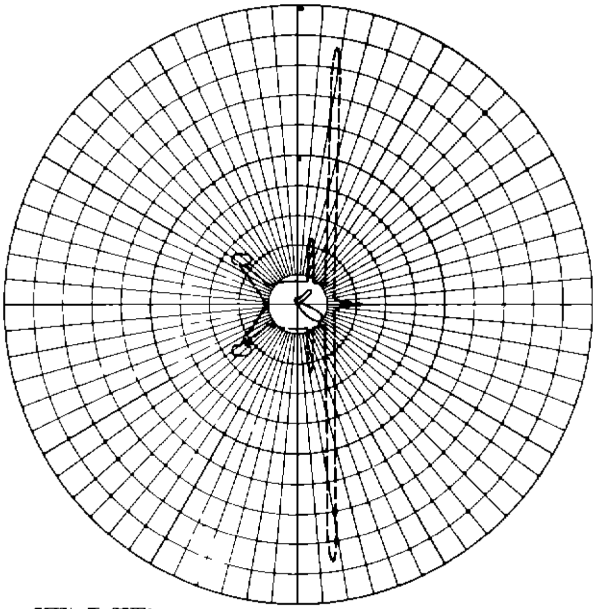
SKETCH OF SYSTEM SHOWING AXIS OF ROTATION

ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	13 B
AXIS OF ROTATION	No. 5
POLARIZATION OF ANTENNA	Plane No. 2
FREQUENCY	1420 Mc.



SKETCH OF SYSTEM SHOWING AXIS OF ROTATION

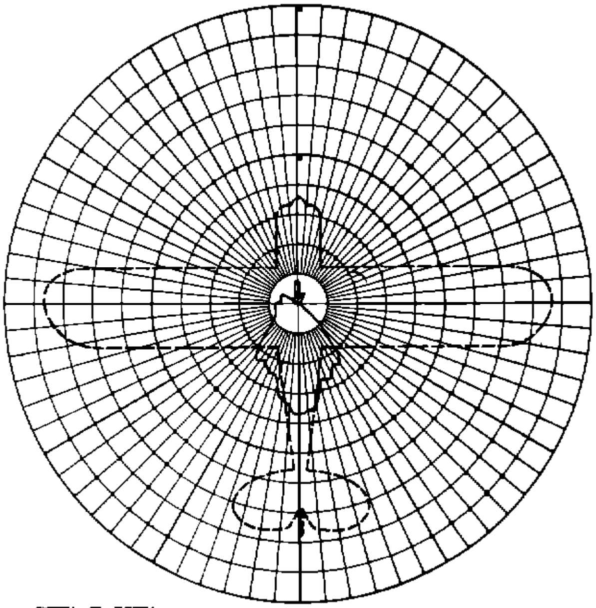
ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	13 D
AXIS OF ROTATION	No. 4
POLARIZATION OF ANTENNA	Plane No. 3
FREQUENCY	1420 Mc



SKETCH OF SYSTEM SHOWING AXIS OF ROTATION

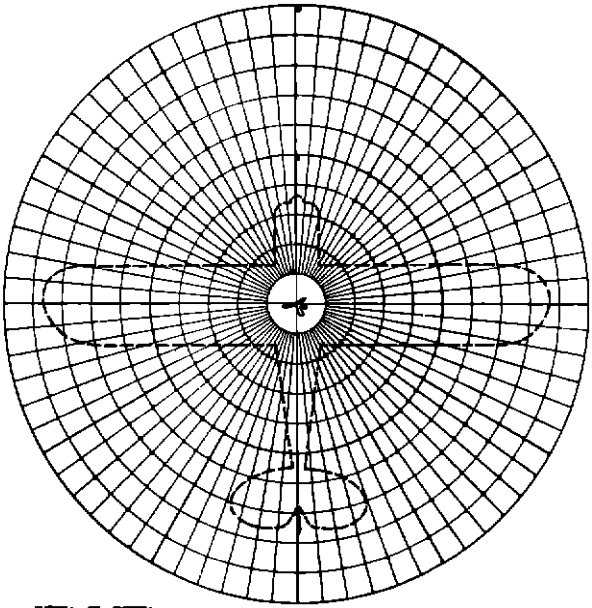
ANTENNA TYPE	V Mounted Above Cabin
PATTERN NO.	13 E
AXIS OF ROTATION	No. 4
POLARIZATION OF ANTENNA	Plane No. 3 Cross
FREQUENCY	1420 Mc.

Fig. 24 V-109 Antenna on Metalized Model at Location 13

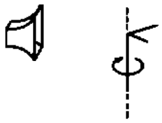


SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

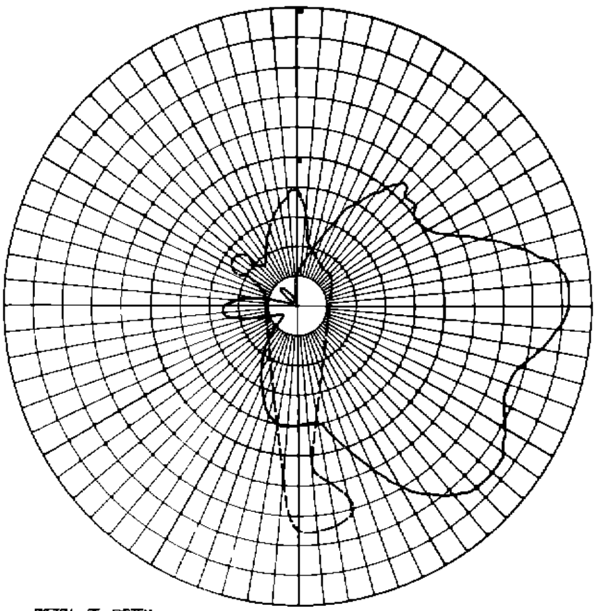
ANTENNA TYPE V Mounted At Rear Of Cabin	
PATTERN NO. 14	
AXIS OF ROTATION No. 6	
POLARIZATION OF ANTENNA Plane No. 1	
FREQUENCY 1420 Mc	



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION



ANTENNA TYPE V Mounted At Rear Of Cabin	
PATTERN NO. 14 A	
AXIS OF ROTATION No 6	
POLARIZATION OF ANTENNA Plane No. 1 Cross	
FREQUENCY 1420 Mc	



SKETCH OF SYSTEM
SHOWING AXIS OF ROTATION

ANTENNA TYPE V Mounted At Rear Of Cabin	
PATTERN NO. 14 B	
AXIS OF ROTATION No 5	
POLARIZATION OF ANTENNA Plane No. 2	
FREQUENCY 1420 Mc	

Fig 25 V-109 Antenna on Metalized Model at Location 14

the received signal voltage can be doubled when the antenna is moved as little as a quarter wavelength (about two feet) This would be true if the antenna initially was located at a point of minimum radiation

Conclusions

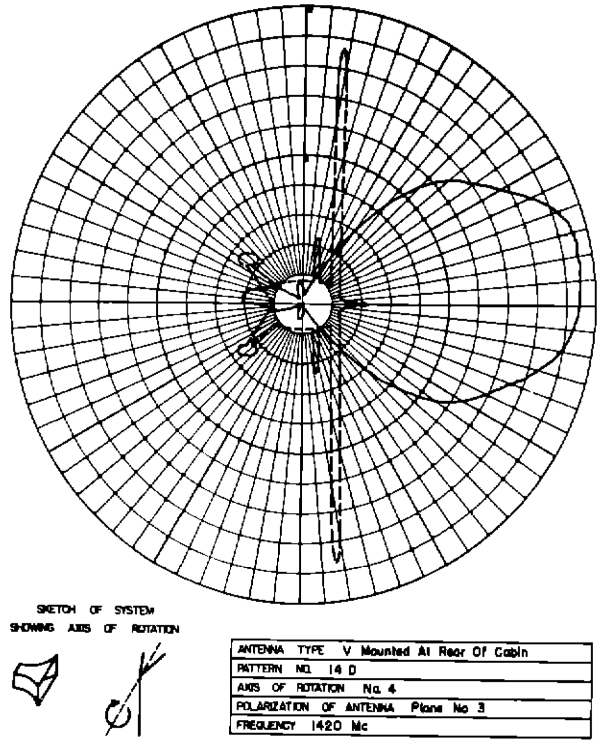
From the results of the metallized model tests it appears that there are few significant differences in the patterns obtained with the metallized and fabric-covered models of the Piper Cruiser Where a shielding effect was observed with the fabric-covered model, similar, but usually more complete shielding was obtained with the metallized model In these model tests no consideration was given to antenna impedance characteristics In actual practice it is very important that the input impedance of the VHF receiver, the output impedance of the antenna and the characteristic impedance of the transmission line between the two be similar over the frequency range employed In the case of a V-type VHF antenna, it is necessary to use the antenna with a balanced-feed system or to employ a balun where unbalanced transmission lines are involved

FLIGHT TESTS

Technique

Full-scale flight tests were made using Piper Cruiser, Stinson Voyager, Ryan Navion and Beechcraft Bonanza aircraft The NARCO Type VRA-1 VHF Receiver, VOA-1 Omnirange Converter and associated equipment, the ERI-Federal VHF noise meter, and the ERI-NARCO VHF noise meter described in Stage I of this report were used in making the tests subsequently described on a number of different antenna arrangements on each of the aircraft The Evansville, Indiana VHF omnirange station (113 3 Mc) was the ground station used in these tests

1 Noise Reduction Noise measurements were made on the ground with the ERI-Federal VHF noise meter to determine the effectiveness of various noise-suppression systems During flight the ERI-NARCO VHF noise meter was used, but with the avc circuit in the NARCO VHF Receiver operating normally, to make relative noise measurements Noise meter readings were taken at 108, 115, and 122 Mc with the receiver tuned off any signals present Readings of as high



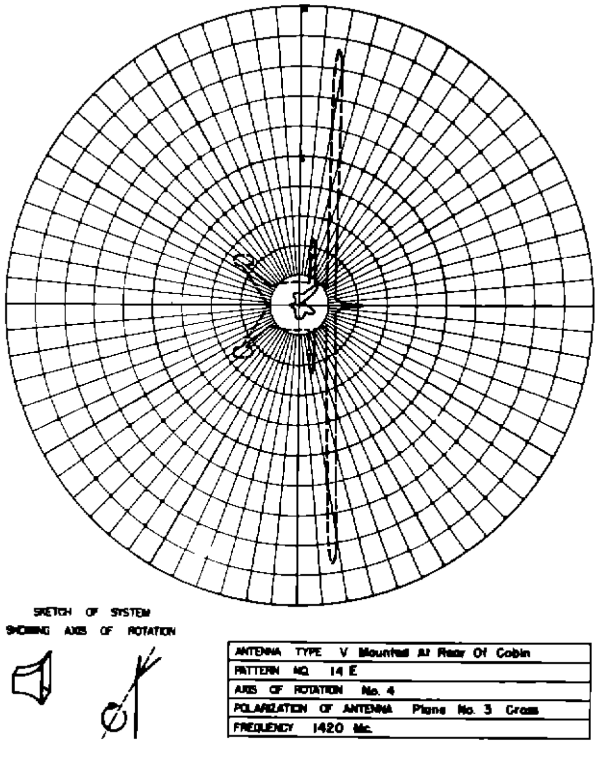


Fig 25 (Continued)

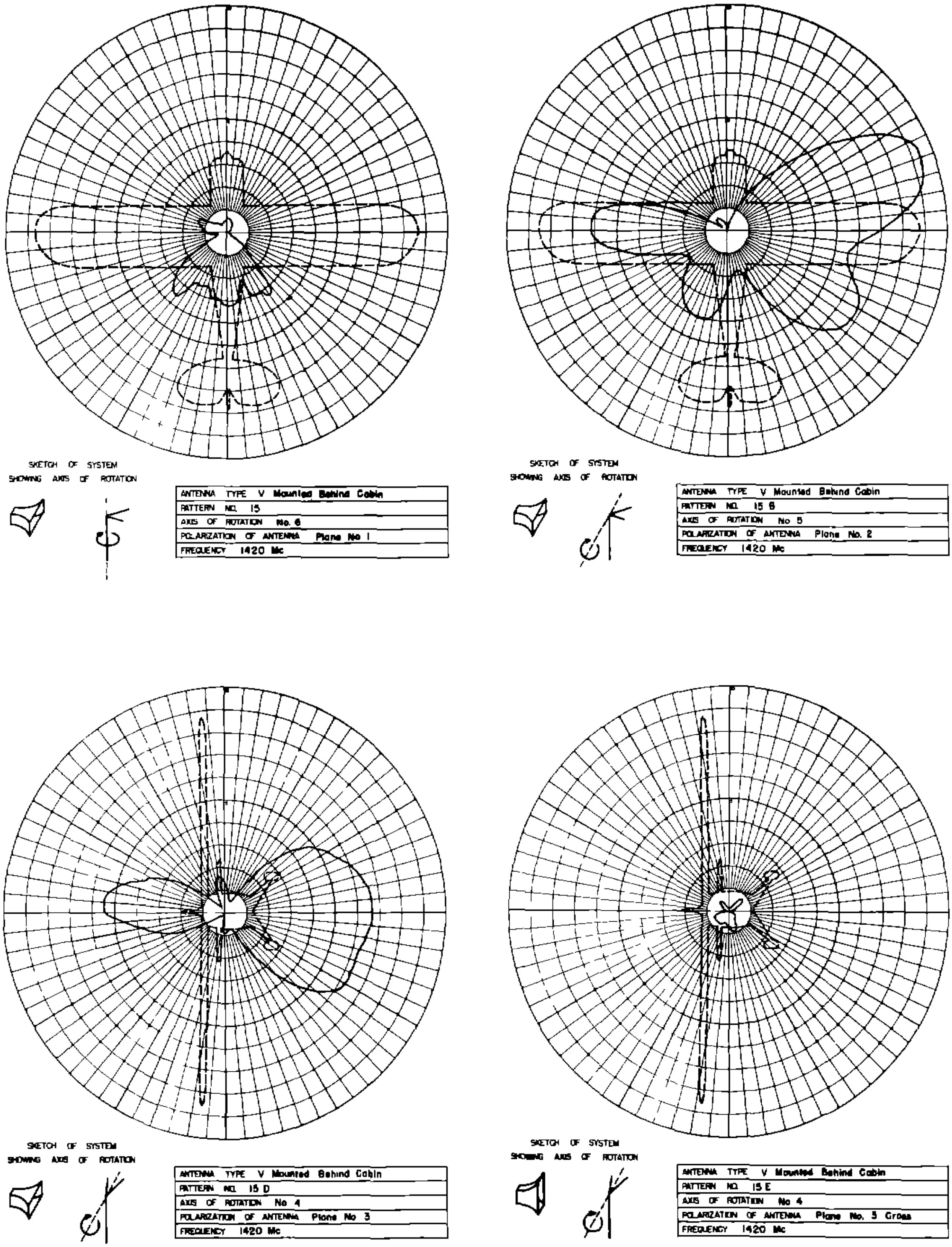
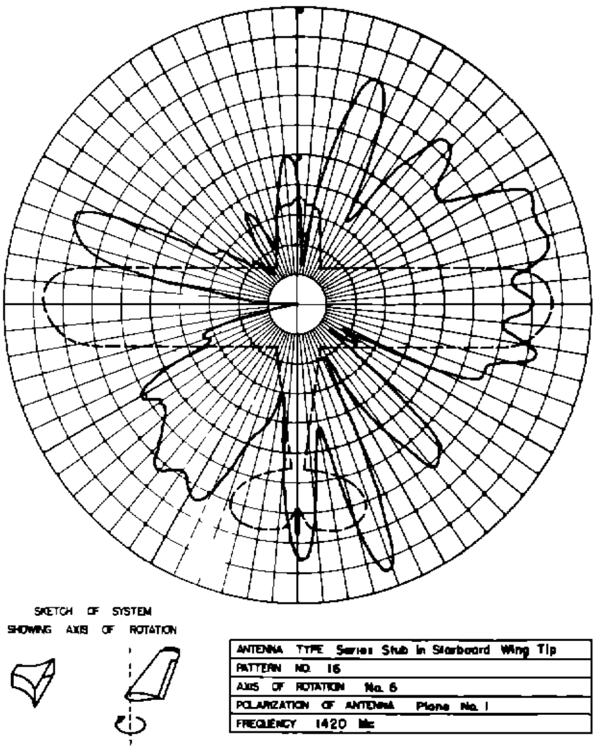
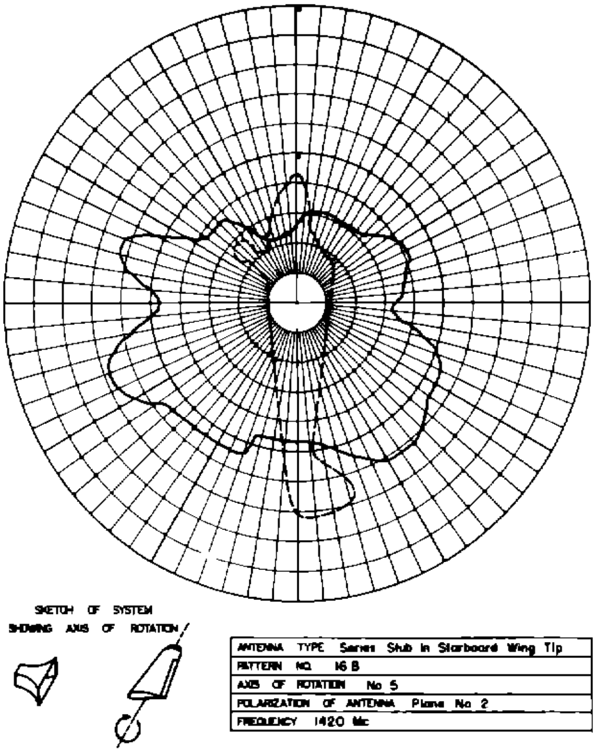


Fig 26 V-109 Antenna on Metalized Model at Location 15





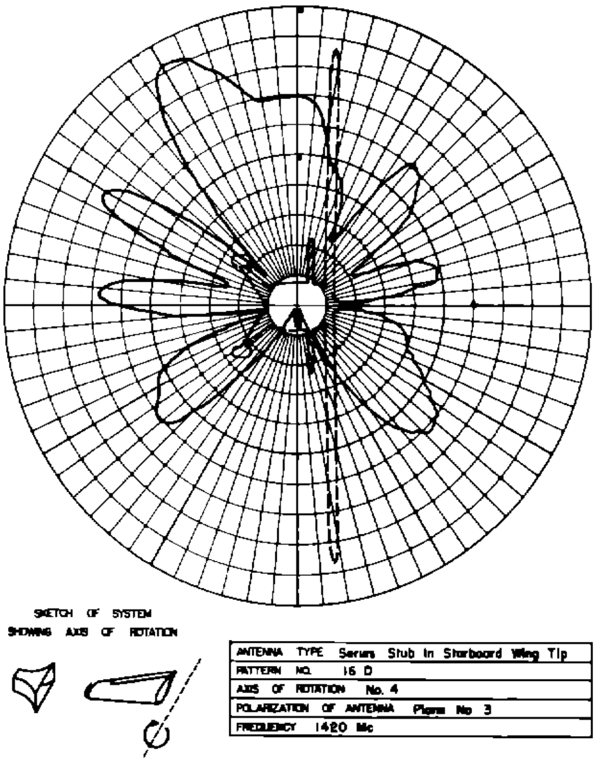


Fig 27 Series-Fed Wing-Tip Antenna on Metalized Model at Location 16

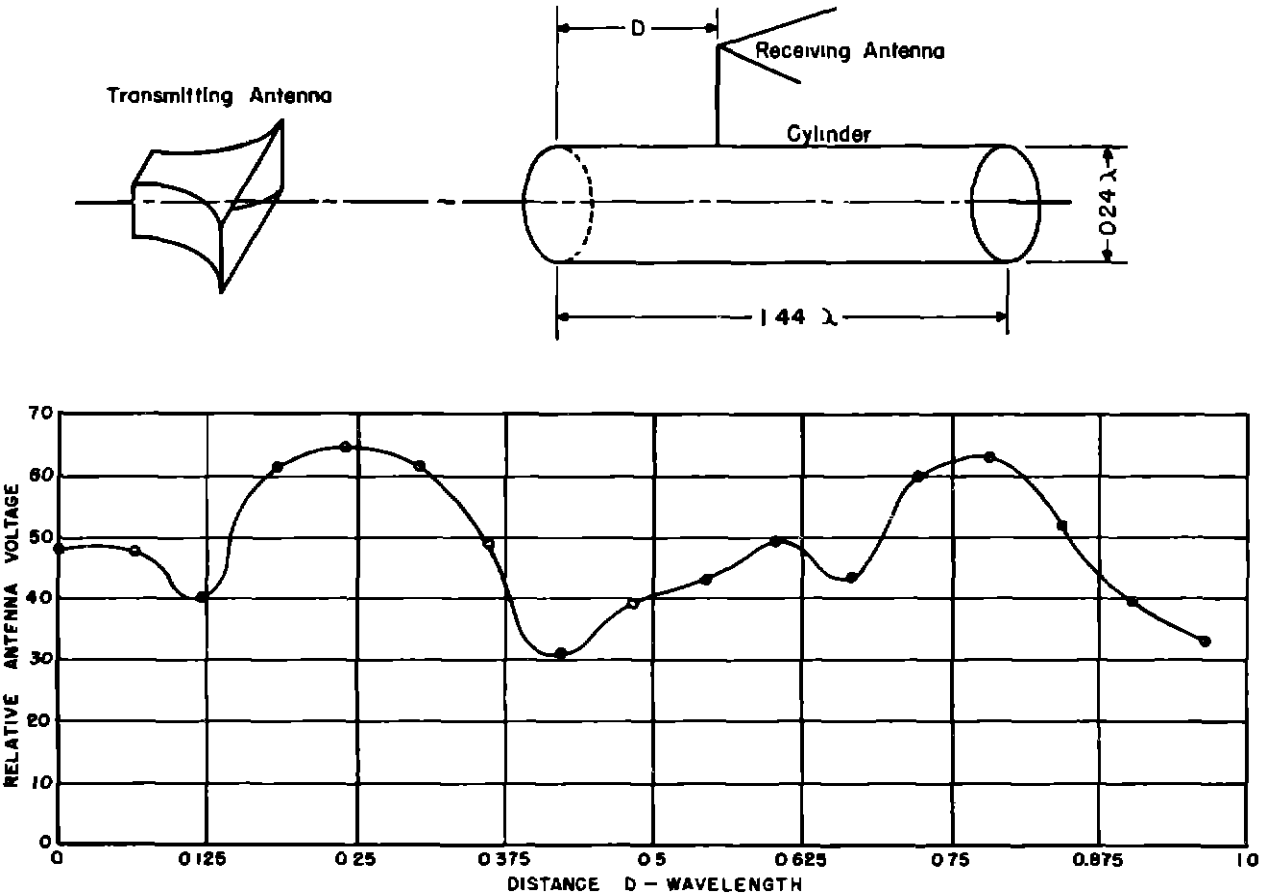


Fig 28 Metal Cylinder Test Effect of Antenna Position on Cylinder

as 1 0 v, corresponding to the audio output obtained with 30 per cent modulated receiver inputs of less than 8 microvolts (Fig 7), were considered good

2 Double Course-Width Distance While the aircraft was flying away from the Evansville omnirange station, at a distance of 15 miles, the course-width was measured with the NARCO equipment Course-width was measured arbitrarily in this manner The OMNIBEARING SELECTOR (referred to hereinafter as OBS) dial was set successively at the points where the course deviation indicator (referred to hereinafter as DI) read full-scale in each direction "Course-width" or DI sensitivity, was defined as the difference between the two OBS dial readings

The flight was continued until the course-width so measured was twice the original value The distance from the range station to the point where the course-width doubled, was recorded These tests were made at an altitude of 1,000 feet The minimum double course-width distance considered acceptable was 45 miles

3 Course-Width at 20 Miles The course-width, as defined previously, was measured at a distance of 20 miles from the Evansville omnirange station with the aircraft headed north, south, east and west A value of 30° was considered optimum course sensitivity

4 Tilt Tests With the aircraft headed toward the Evansville omnirange station, at a distance of about 25 miles, the pointer of the DI was centered and the wings were tipped 45° to the right for a few seconds and then 45° to the left for the same period The amount of DI meter deflection caused by these maneuvers was recorded Three degrees was considered tolerable

5 Readability Limit The greatest distance at which the voice transmission from the Evansville omnirange station was readable was noted with the aircraft flying due north

away from the station at an altitude of 1,000 feet The test was repeated with the aircraft headed toward the station and the distance where the voice transmissions were again readable was noted It was found that the distance was approximately the same for both directions of flight, inasmuch as the exact limit of readability could not be precisely determined by this measuring technique The average of the two readings was recorded A range of 50 miles was required

6 Propeller Modulation The pointer of the DI was centered and the speed of the aircraft engine was varied slowly A slight oscillation of the indicator was noted at certain speeds and its magnitude was recorded at the most critical points, 1800, 2100 and 2400 rpm A maximum of 3° was considered tolerable

7 Pattern Measurements Pattern measurements were made at a distance of about 25 miles from the Evansville omnirange station at altitudes of 1000, 2000 and 4000 feet Readings were taken at heading intervals of 45° as the aircraft flew over a fixed landmark The ERI-NARCO VHF noise meter was used with appropriate external attenuators in recording the received voltages for each heading of the aircraft

8 Bearing Error at 20 Miles Bearing readings over a fixed landmark 20 miles due north of the Evansville omnirange station, as indicated by the NARCO equipment, were recorded with the airplane headed N, NE, E, SE, S, SW, W, and NW Errors of less than 3° were considered acceptable

9 Bearing Error in 30° Bank Bearing readings over a fixed landmark 20 miles due north of the Evansville omnirange station, as indicated by the NARCO equipment, were recorded with the airplane headed N, NE, E, S, SW, W, and NW, flying in a 30° bank in a circle around the landmark Errors of less than 3° were considered desirable but not absolutely essential

Data

Most of the data taken during the flight tests is given in tabular form in Tables I and II The various antenna arrangements tested were identified by flight numbers which appear in Table I A description of the installations involved for each of the flight numbers is given where individual tests are discussed The test numbers in Table I correspond to the numbers given each of the tests and describe the technique used Locations of the tested antennas are given for the corresponding flight numbers in Fig 29 Pattern data is given in Table II, and graphically in Fig 31 The last column of Table II gives the value of input attenuator used with the ERI-NARCO noise meter for each set of data The attenuator setting can be used with the tabulated values and Fig 7 to obtain the approximate radio frequency output voltages from the tested antennas In Tables I and II all signal and noise intensity readings are given in terms of output voltage of the ERI-NARCO VHF noise meter

Piper Cruiser, Flights 1 and 2

The CAA V-109 antenna was mounted over the cabin of the Piper Cruiser on the center line of the aircraft, 7 1/2 inches behind the windshield as shown in Figs 29 and 30 Preliminary flights with this installation revealed that ignition noise was objectionable on the NARCO receiver at a distance of only 25 miles from the Evansville omnirange station Ground tests with the ERI-Federal VHF noise meter revealed that resistance spark plugs reduced this noise by a factor of 15 1 db, and shielding the ignition system resulted in a 29 db noise reduction at which point no noise could be heard in the receiver headphones By "shielded ignition system" is meant shielded spark plugs, wiring and magnetos

Flight 1 was made with resistance spark plugs installed and Flight 2 with the shielded ignition system Examination of the data in Table I leads to the conclusion that either noise-suppression system is acceptable inasmuch as satisfactory performance was obtained at well over 45 miles at an altitude of 1,000 feet The 3° deflections of the DI pointer obtained in the tilt and propeller modulation tests are within acceptable limits, but the errors measured in the 30° bank tests were rather high

The antenna lead-in used for all of the Piper Cruiser flight tests was 7 5 feet of RG-58/U cable Lead-in lengths of 90, 100 and 110 inches of RG-58/U, RG-54/AU and RG-29/U, all 50-ohm coaxial cables, were tested on the ground As might be expected, there was no noticeable change in performance with any of the cable arrangements

Antenna pattern data is given in Table

TABLE I

Stage II Flight Test Data

Aircraft	Flight	Test #1 Noise Reduction Noise Voltage			Test #2 Double Course Width Distance, Miles		Test #3 20 Mile Course Width, Degrees				Test #4 Tilt Deflection, Degrees		Test #5 Readability Limit, Miles	Test #6 Propeller Modulation Deviation, Degrees		
		108 mc	115 mc	122 mc.	To	From	North	East	South	West	To	From		1800 rpm	2100 rpm	2400 rpm
Piper	1	1 9	1 5	1 6	48	46	25	34	25	39	3	3	53	3	3	1 5
"	2	0 5	0 7	0 5	49	47	30	30	27	33	1 5	0	53	3	3	1 5
"	3															
Stinson	4	5 5	4 6	5 0	36	34	35	40	40	45	1	1	45	3	0	0
"	5	1 8	1 5	1 6	49	46	35	35	34	35	3	1 5	54	3	0	0
"	6	0 5	0 7	0 6	53	53	30	34	31	37	1 5	0	56	3	0	0
"	7	0 5	0 7	0 6	43	48	30	37	30	38	1 5	1	54	1 5	0	0
Navion	8	0 3	0 4	0 4	48	48	38	39	37	42	1 5	1 5	57	0	0	0
"	9	0 2	0 2	0 2	46	44	37	39	38	40	0	0	53	3	0	1 5
"	10	0 2	0 2	0 2	36	37	38	40	38	41	3	3	48	1 5	1 5	3
Beechcraft	11	0 4	0 4	0 5	45	46	35	42	35	43	1 5	1 5	54	0	0	0
"	12	0 3	0 4	0 4	32	46	34	50	37	41				1 5	0	1 5

Aircraft	Flight	Test #8 Bearing Error At 20 Miles, Degrees								Test #9 Bearing Error In 30° Bank, Degrees							
		N	NE	E	SE	S	SW	W	NW	N	NE	E	SE	S	SW	W	NW
Piper	2	-1	+1	0	-1	0	0	0	0	-4 5	0	0	-1	-6	-4 5	-6	-4 5
Stinson	6	+1	-1	+2	0	0	+1	-1	+1	+1	+1	+1 5	0	-3	-3	-3	-4 5
Navion	8	0	-1	-1	0	0	0	-1	0	-3	-4 5	0	+3	+1	0	-3	-4 5

II and the patterns obtained are shown in Fig 31 The patterns appear to be reasonably symmetrical and are satisfactory

Piper Cruiser, Flight 3

A series-fed wing tip antenna was installed on the starboard wing of the Piper Cruiser as shown in Figs 20 and 29

No detailed flight data on this antenna was taken because of time limitations However, in preliminary flights it was observed that propeller modulation was not noticeable at any engine speed Measurements made on the ground with no suppressor system installed revealed that ignition noise picked up by this antenna was 6 db below that of the V-109 as mounted above the cabin for Flights 1 and 2

Stinson Voyager, Flight 4

Flight 4 on a Model 150 Stinson Voyager Airplane was made with the CAA V-109 antenna over the cabin, 13 1/2 inches behind the upper edge of the windshield on the center line of the aircraft as shown in Figs 29 and

TABLE II

Stage II Flight Pattern Data

Aircraft	Flight	Relative Received Voltage At Heading Of								Altitude Feet	Distance Miles	Attenuator db
		0°	45°	90°	135°	180°	225°	270°	315°			
Piper	2	3 80	3 40	2 40	2 80	2 70	1 50	1 50	3 20	1000	33	6
		3 90	3 40	2 80	3 20	3 60	2 40	1 80	3 60	2000	36	6
		4 80	4 00	2 50	3 40	3 60	1 60	1 70	3 70	4000	36	12
Stinson	6	4 00	4 00	2 40	3 00	3 50	3 70	1 60	3 50	1000	36	0
		4 80	4 60	2 60	3 20	4 00	3 80	2 40	3 80	2000	45	6
		4 70	4 00	2 80	3 40	3 80	3 70	2 10	4 00	4000	45	12
"	7	3 60	3 80	1 60	4 00	4 60	3 60	2 00	2 40	1000	33	6
		4 00	2 80	1 60	3 40	4 90	2 60	2 00	2 20	2000	33	12
		3 80	3 80	1 40	3 60	4 20	3 80	2 00	2 20	4000	36	12
Navion	8	1 80	1 00	0 70	1 45	1 50	1.55	0 65	1 10	1000	26	12
		3 30	1 80	1 50	3 40	3 20	3.50	2 00	2 30	2000	26	12
		4 70	4 30	3 80	4 80	4 70	4 80	3 30	4 80	4000	26	12
"	9	1.80	1 30	0 40	0 60	1 00	1 20	0 50	1 80	1000	18	12
		3 10	3 00	0 70	2 60	2 80	3 20	1 80	3 30	2000	18	12
		2 30	2 90	2 40	2 80	3 20	2 70	3 10	2 40	4000	18	12
"	10	0 90	0 80	0 35	0 70	0 60	0 25	0 40	0 90	1000	18	12
		2 20	2 40	1 00	1 70	1 80	1 80	1 20	2 30	2000	18	12
		2 90	2 70	2 80	3 20	3 00	2 70	3 10	2 80	4000	18	12
Beechcraft	11	3 40	1 90	1 25	2 70	2 10	2 10	1 40	1 90	1000	18	12
		4 20	1 60	1 20	2 40	2 90	1 75	1 20	1 50	2000	18	12
		3 20	4 30	4 30	4 30	3 50	4 20	4 20	4 20	4000	18	12
"	12	0 60	0 60	0 40	0 50	1 45	0 90	0 50	0 45	1000	18	12
		1 35	1 05	0 65	1 00	1 85	1 60	1 20	0 80	2000	18	12
		4 40	4 20	2 80	3 80	3 40	4 20	4 30	3 80	4000	18	12

32 Noise measurements made before take-off indicated that ignition noise in the receiver was 7 db above that in the Piper Cruiser without noise-suppression systems Resistance spark plugs lowered the noise level 5 db and shielding the ignition system caused a 37 db noise reduction Flight 4 was made using resistance-wire ignition leads The figures in the Test 1 column of Table I show that the ignition noise level was rather high, reducing the double course-width distance to about 35 miles, and causing generally unsatisfactory performance

Stinson Voyager, Flights 5 and 6

Flights 5 and 6 were made with the same antenna installation as in Flight 4 Resistance spark plugs were used in Flight 5 and a completely shielded ignition system was used in Flight 6 Examination of the data in Table I reveals that satisfactory results were obtained on both flights, but that the shielded ignition system was superior Overall performance was similar to that obtained with the Piper Cruiser The antenna lead-in for Stinson Voyager Flights 4, 5 and 6 consisted of 100 inches of RG-58/U cable

Stinson Voyager, Flight 7

For Flight 7 the CAA V-109 antenna was moved to a point 37 1/2 inches behind the upper edge of the windshield on the center line of the Stinson Voyager aircraft as illustrated in Fig 29 This was the location of the VHF whip antenna in the view shown in Fig 32 Ignition noise measurements on the ground showed that reductions of 6 db with resistance spark plugs and 42 db with a shielded ignition system could be obtained

The antenna patterns, Fig 31, show unsatisfactory forward sensitivity, the course-width doubled well before the desired mini-

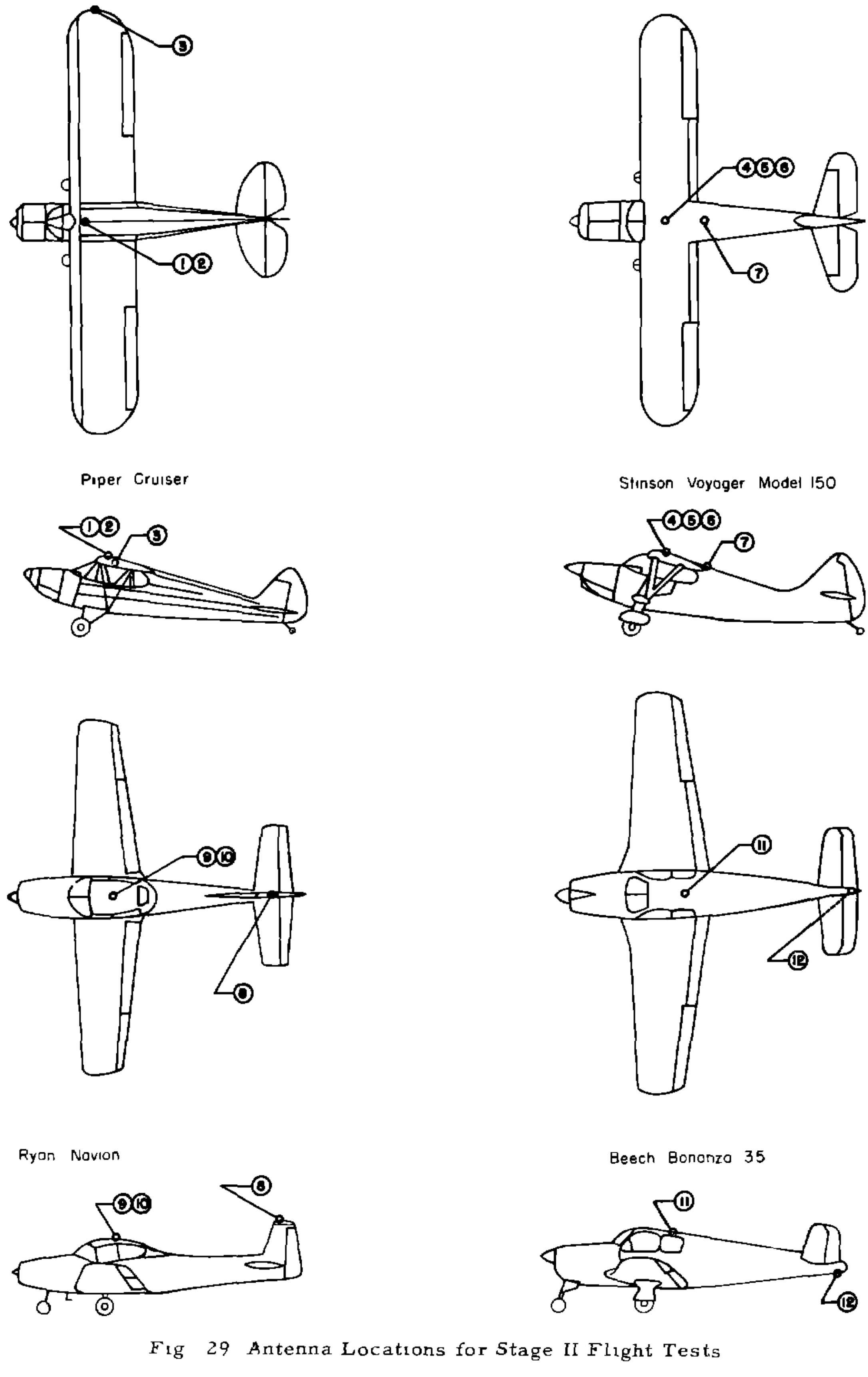


Fig 29 Antenna Locations for Stage II Flight Tests

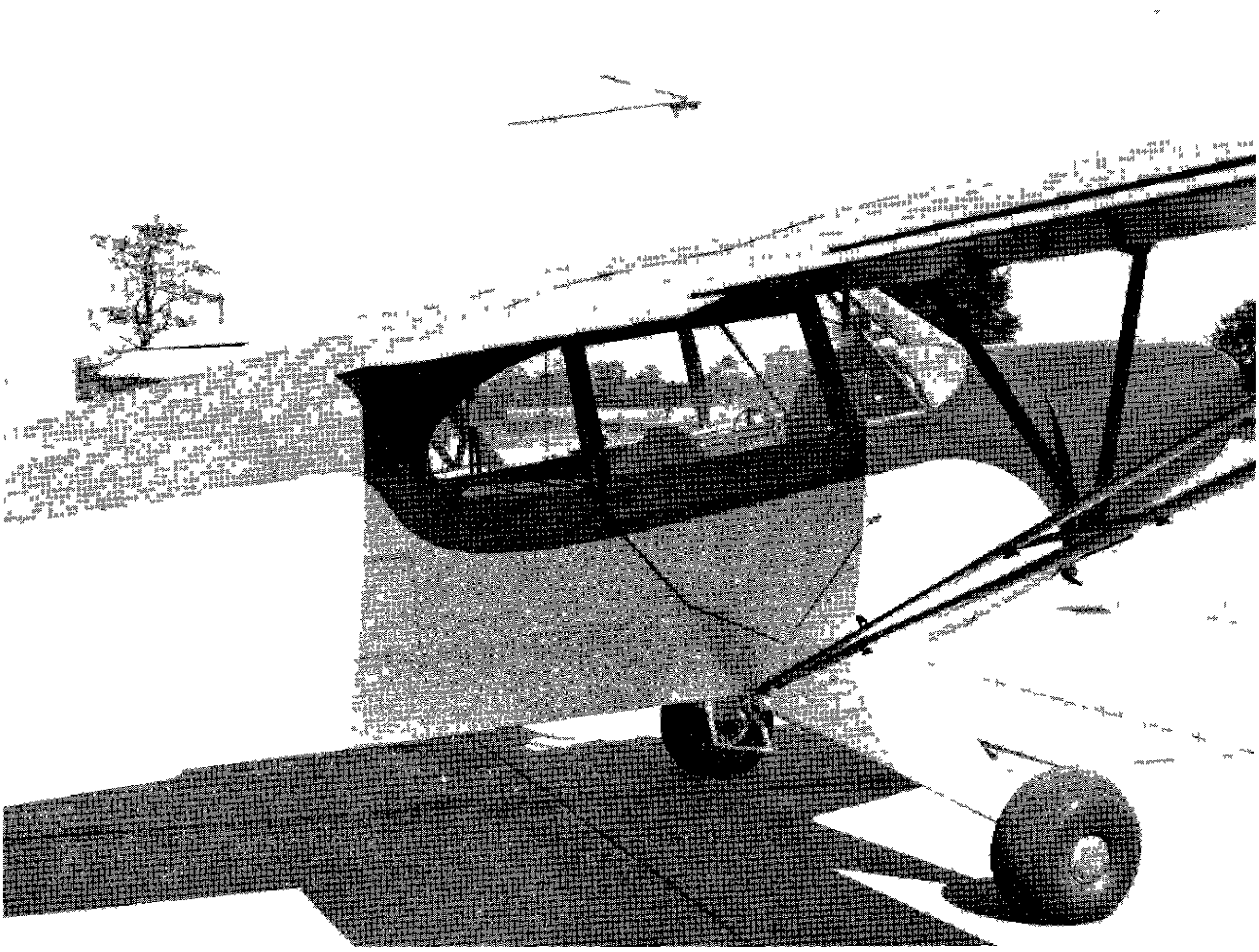


Fig 30 V-109 Antenna on Piper Cruiser

mum of 45 miles, and performance was generally unsatisfactory

Navion, Flight 8

The CAA V-109 antenna was installed above the vertical stabilizer (see Figs 29 and 33) on a Model 1949 Ryan Navion aircraft for Flight 8 Measurements on the ground indicated that the VHF noise level on the Navion was about 6 db above that of the Piper Cruiser with shielded ignition system Excellent results were obtained in all flight tests See Tables I and II and Fig 31 A rather long lead-in, 22 5 feet of RG-29/U cable, was used in this installation Lead-in loss was approximately 1 db, but this was negligible in this installation

Navion, Flight 9

The CAA V-109 antenna was installed above the cabin on the Navion, 19 inches behind the windshield on the center line of the aircraft, as shown in Fig 29 A 21 5 foot length of RG-29/U cable was used for the antenna lead-in The results obtained at this position, as given in Tables I and II and Fig 31, show that this antenna location is inferior to the vertical stabilizer location used for Flight 8 The pattern at 1,000 feet shows that there is insufficient signal pickup to the rear, causing poor course sensitivity characteristics

Navion, Flight 10

A NARCO V antenna was mounted on the Navion cabin in the same location as that for the V-109 antenna in Flight 9 See Figs 29 and 34 Results obtained with this in-

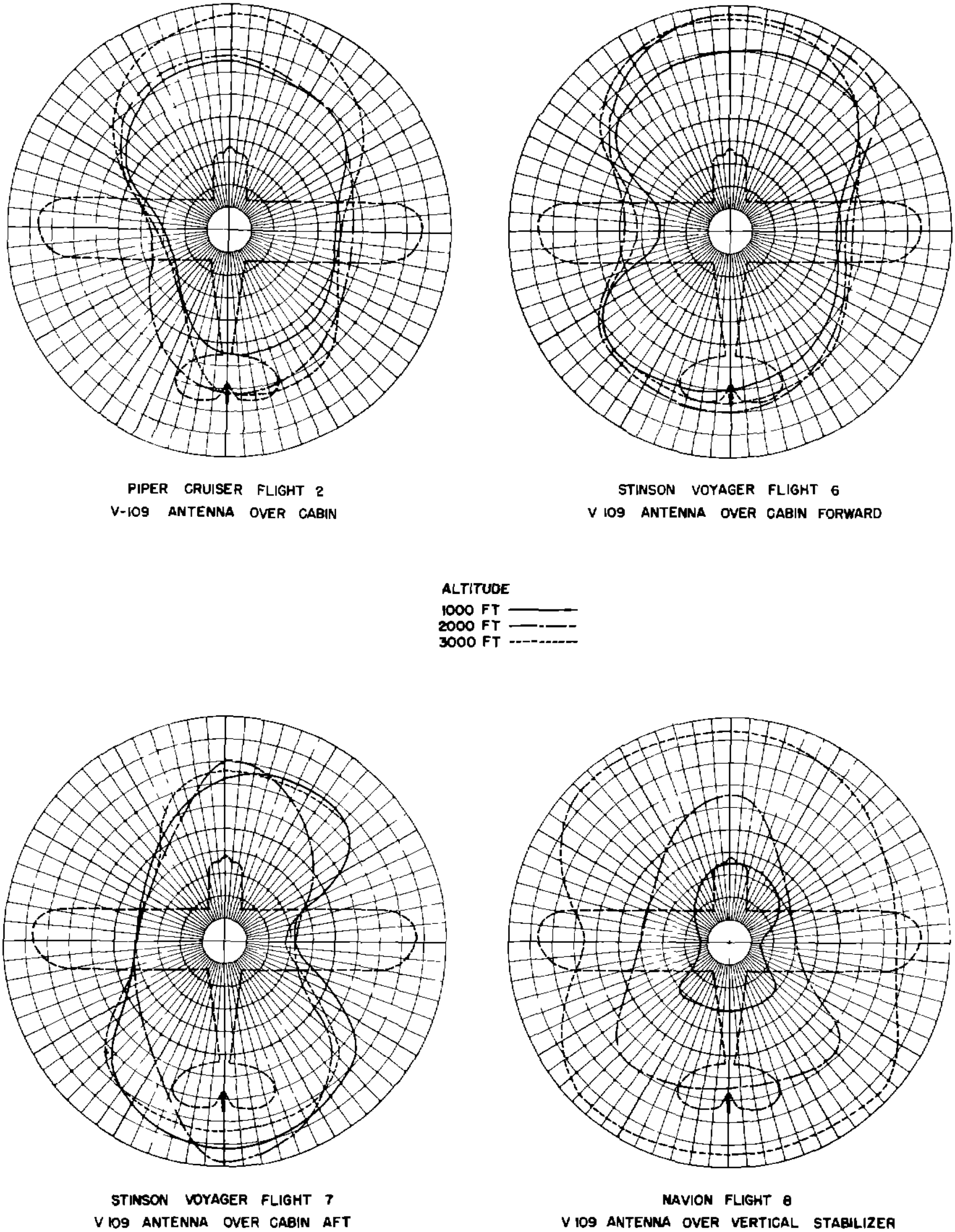
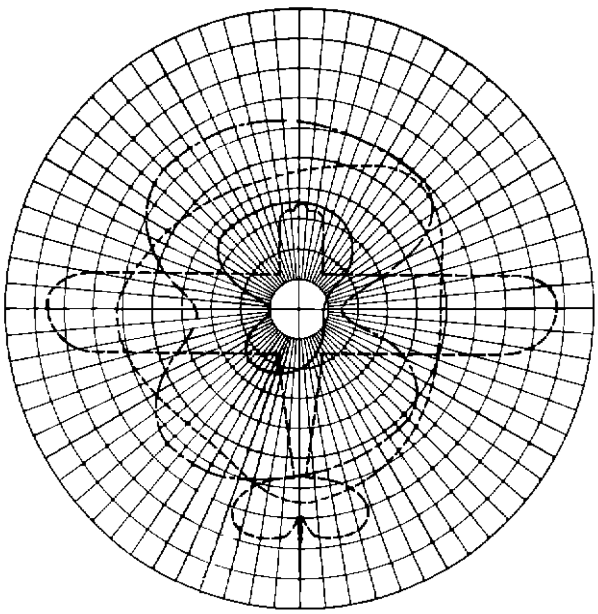
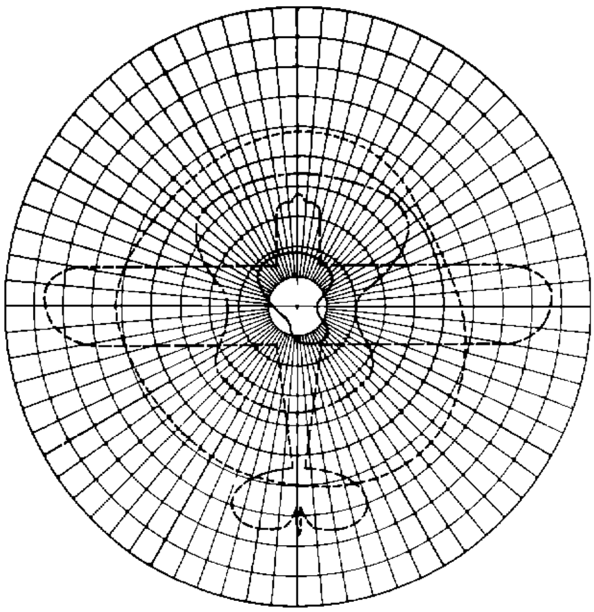


Fig 31 Stage II Flight Patterns

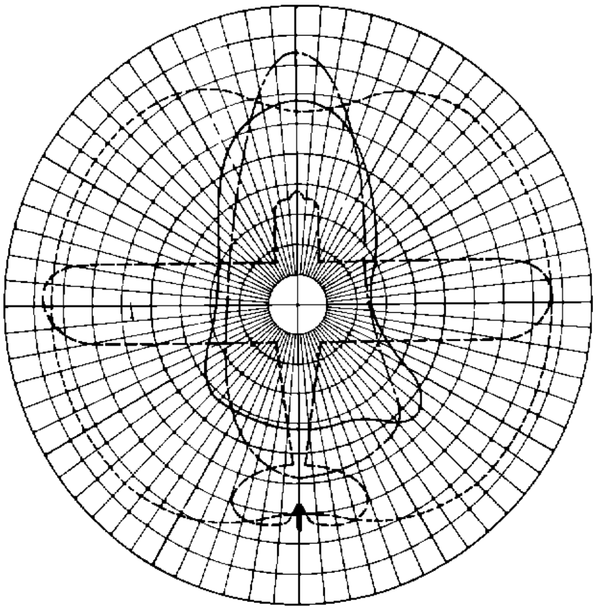


NAVION FLIGHT 9
V-109 ANTENNA OVER CABIN

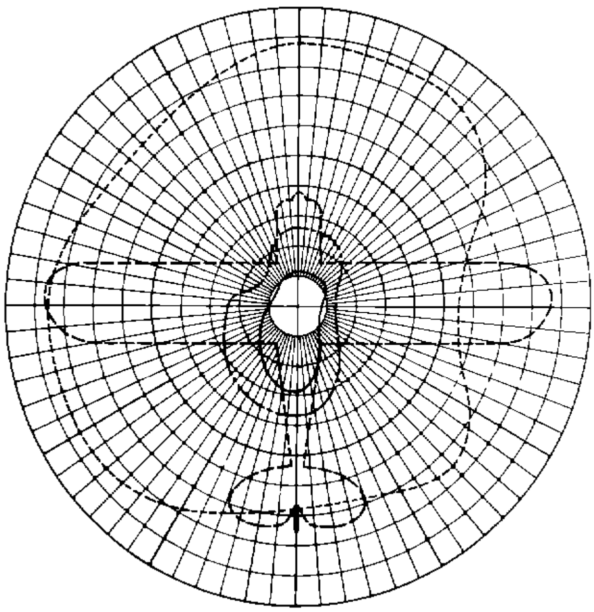


NAVION FLIGHT 10
NARCO ANTENNA OVER CABIN

ALTITUDE
1000 FT ————
2000 FT —·—·—
3000 FT ---------



BEECHCRAFT BONANZA FLIGHT 11
PIONEER V ANTENNA OVER CABIN



BEECHCRAFT BONANZA FLIGHT 12
V-109 ANTENNA BELOW TAIL

Fig 31 (Continued)

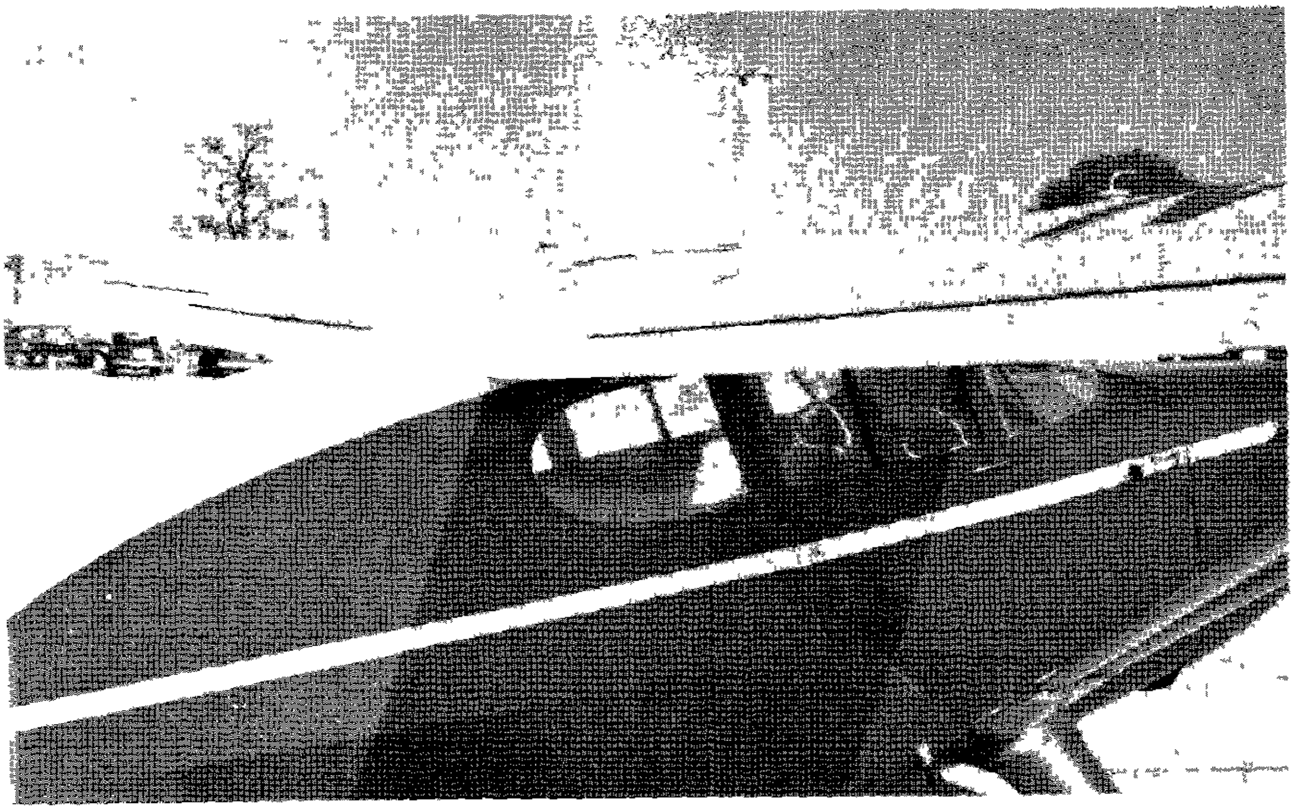


Fig 32 V-109 Antenna on Stinson Voyager

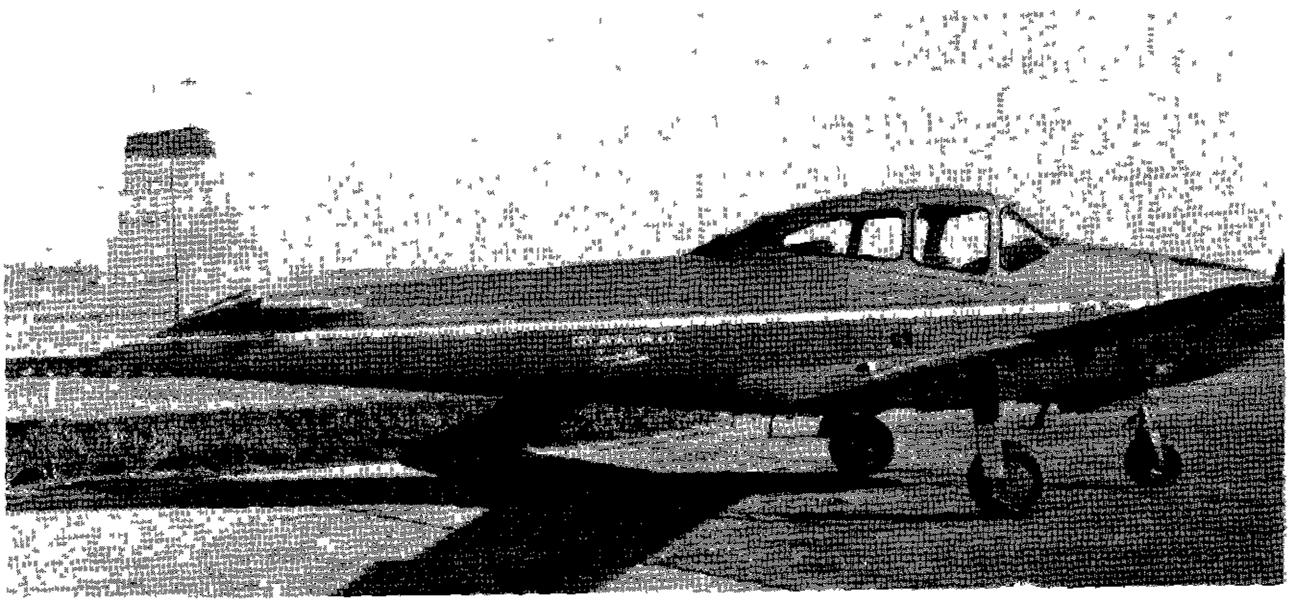


Fig 33 V-109 Antenna on Navion Vertical Stabilizer

stallation were generally inferior to those obtained with the V-109 antenna at the same location and the performance was vastly inferior to that obtained at the vertical stabilizer location in Flight 8 See Tables I and II and Fig 31 The sensitivity of the NARCO antenna appears to be considerably less than that of the CAA V-109 antenna See Appendix II

Beechcraft Bonanza, Flight 11

Figs 29 and 35 show the location of the Pioneer V antenna on a Model 35 Beechcraft Bonanza aircraft for Flight 11 A low-frequency wire antenna located near the VHF antenna to be tested can be seen in Fig 35 This wire antenna had to be removed before satisfactory results could be obtained Measurements made on the ground indicated that the VHF noise level in the Beechcraft Bonanza was 14 db above that in the Piper Cruiser with shielded ignition system The antenna lead-in consisted of 120 inches of RG-29/U coaxial cable As can be seen from the data in Tables I and II and the antenna patterns in Fig 31, generally satisfactory results were obtained

Beechcraft Bonanza, Flight 12

The vertical pedestal was removed from a CAA V-109 antenna and the antenna was mounted below the tail of the aircraft as shown in Figs 29 and 36 The lead-in consisted of 20 feet of RG-29/U cable The data and patterns obtained at this installation are given in Tables I and II and Fig 31 The installation was unsatisfactory since the double course-width distance was as low as 32 miles

CONCLUSIONS

It is concluded that the most satisfactory method of suppressing VHF ignition noise on small aircraft is the employment of a shielded ignition system However, the employment of resistance spark plugs as a means of noise suppression gives satisfactory results Noise reductions obtained using resistance spark plugs over systems with no suppression were approximately 10 db With shielded ignition systems, the noise reduction was about 30 db

Where shielded ignition systems are employed, almost any location of the VHF receiving antenna is satisfactory from a noise standpoint When resistance spark plugs are used as the sole means of noise suppression it appears advisable to locate the VHF receiving antenna as far away from the aircraft engine as other considerations will permit

VHF receiving-antenna lead-ins using standard types of 50-ohm coaxial cable (such as RG-29/U and RG-58/U) are satisfactory for small aircraft While it appears desirable to run the lead-in by as short and direct a route as possible, the route used is not critical

Propeller modulation was negligible at all antenna locations tested The maximum oscillation of the NARCO DI pointer observed was approximately 3°

The most critical factor involved in the placement of VHF receiving antennas on small aircraft is the location effect on the antenna pattern It is necessary to locate the antenna in a position which will give a good horizontal pattern on the horizon and a few degrees below, if optimum performance is to be obtained with the VHF navigation equipment The best locations found on the tested aircraft were, over the cabins of the Piper Cruiser (Point 1, Fig 29) and Stinson Voyager (Point 6, Fig 29), above the vertical stabilizer of the Navion (Point 8, Fig 29), and over the cabin on the Beechcraft Bonanza (Point 11, Fig 29)

In general, it appears that the best position for the VHF receiving antenna on small aircraft is well forward over the cabin. Where a high vertical stabilizer is available this location also is good

STAGE III

RECEIVER LOCATION STUDY

Stage III of the work program was a study of all convenient locations for the VHF receiver and interconnecting cables on Piper Cruiser, Stinson Voyager and Ryan Navion aircraft to determine the parameters for minimum ignition noise

LOCATION TESTS

Technique

The ERI-NARCO VHF noise meter, with the antenna replaced by a 50-ohm shielded resistor, was used as the receiver in the tested aircraft The noise meter output reading was recorded at 108, 115 and 122 Mc and was used as a basis for judging the quality of

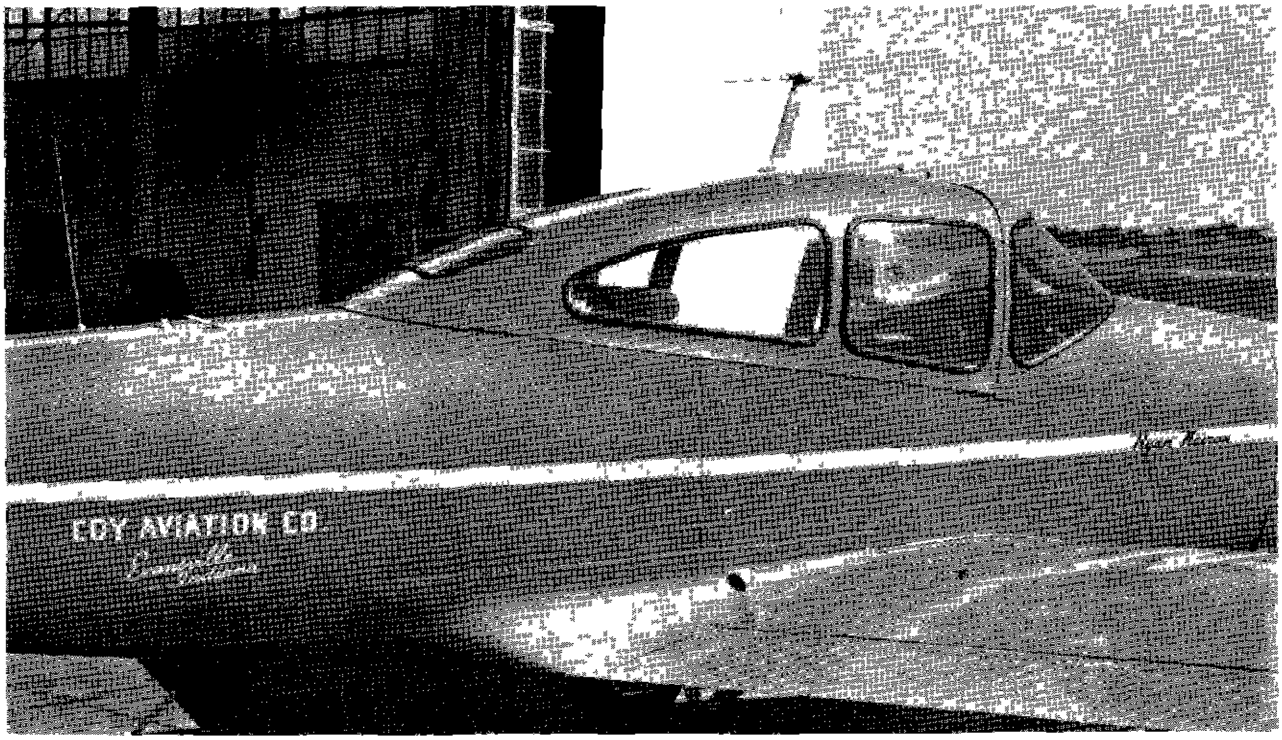


Fig 34 NARCO Antenna on Navion Cabin

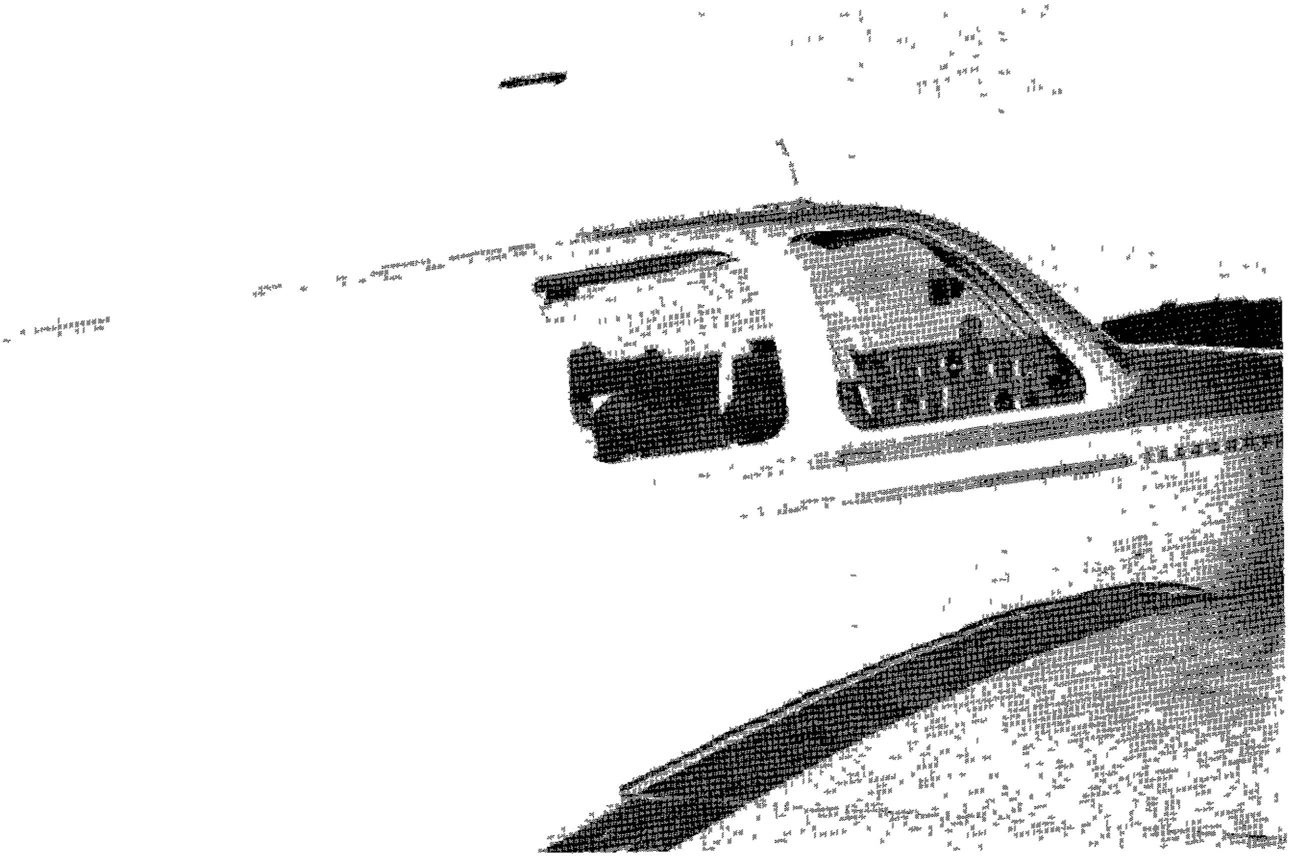


Fig 35 Pioneer V Antenna on Beechcraft Bonanza

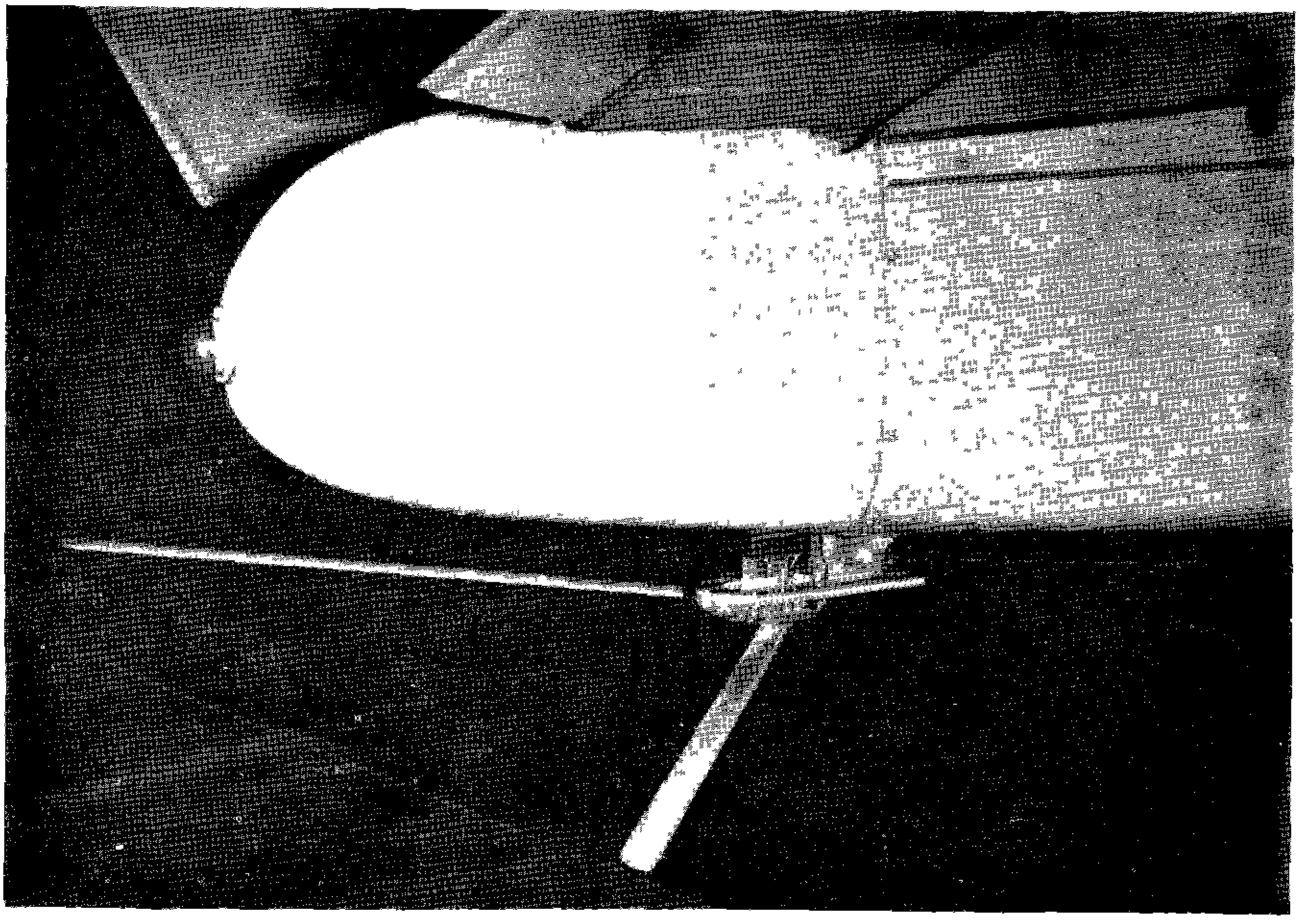


Fig 36 V-109 Antenna on Beechcraft Bonanza

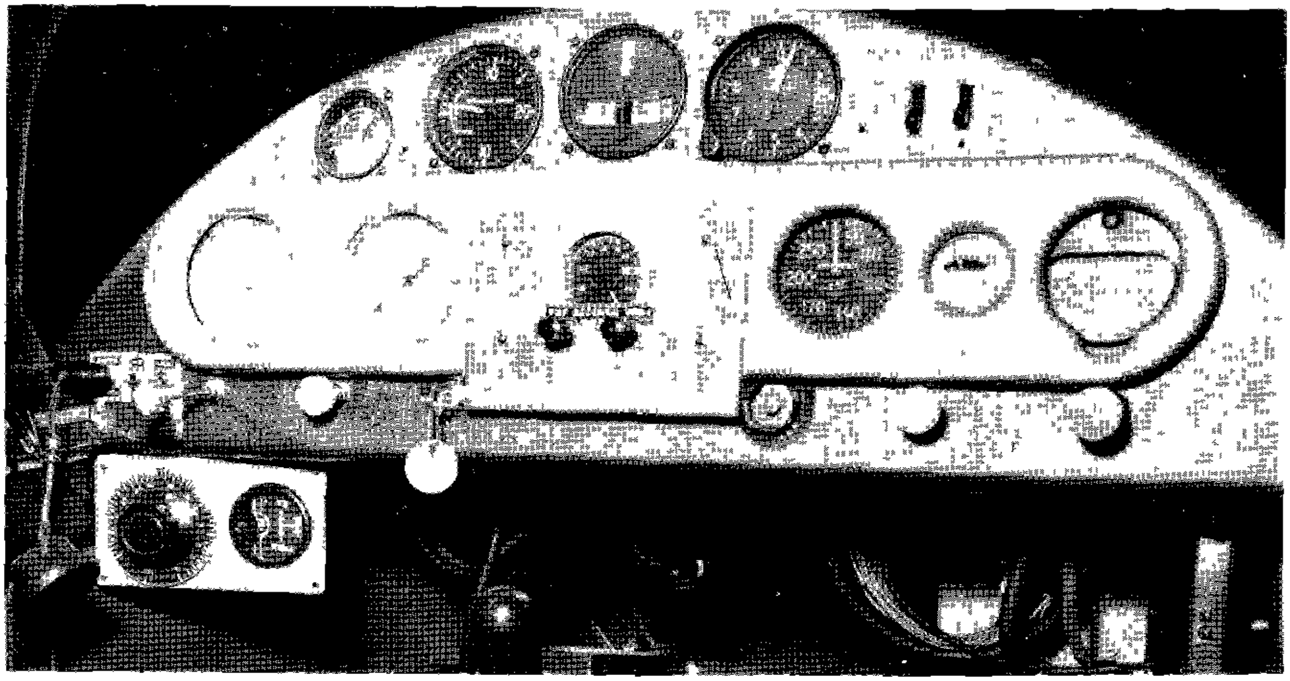


Fig 37 Piper Cruiser Receiver Installation

various installations.

The shielded ignition system of noise suppression was in use on each of the tested aircraft. It was felt that this did not have any bearing on the results obtained since good noise suppression would be required for any satisfactory VHF receiving installation. Except where otherwise noted, shielded inter-connecting power cables were used with the NARCO equipment.

Piper Cruiser

The NARCO VHF Receiver and associated equipment were installed on the Piper Cruiser as shown in Fig 37, which shows the receiver unit at the center of the instrument panel, the OBS dial assembly at the left below the instrument panel, the course deviation indicator at the right end of the instrument panel, and the omniconverter and power supply above the rudder pedals

The noise meter output readings for the aforenamed location at 108, 115 and 122 Mc were 0.45, 0.65 and 0 45 v respectively These values correspond to the audio output obtained with a 30 per cent modulated radio frequency input voltage of about 5 microvolts at the antenna terminals of the receiver See Fig 7 Actually, these voltages are so low that they are hardly above the residual noise level of the receiver

The receiver equipment was mounted on an aluminum panel, as shown in Fig 38, so that it could be quickly moved about to make location tests. Measurements were made with this portable assembly located in the front and rear seats of the Piper Cruiser, and in all cases the noise meter readings were the same as those obtained with the instrument-panel installation

Stinson Voyager

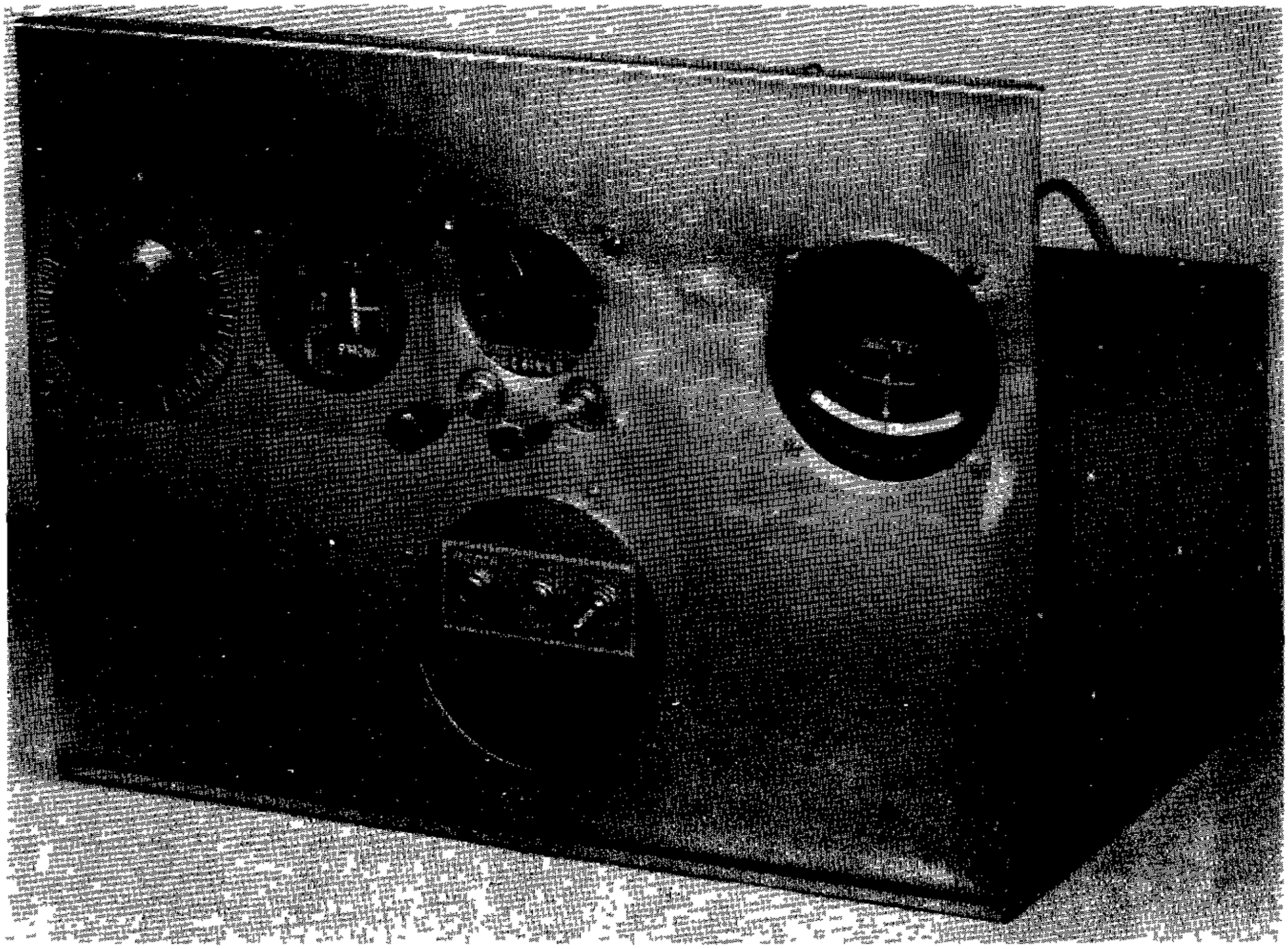


Fig 38 Portable NARCO VHF Receiver Assembly

The NARCO VHF receiver installation shown in Fig. 39 was tested on a Stinson Voyager The receiver is seen in the photograph just to the right of center on the instrument panel, and the omniconverter and power supply, mounted above the rudder pedals, are not visible. Tests were also made with the portable receiver assembly of Fig. 38 in the front and rear seats.

For all locations the noise meter output was the same and was 0.85, 0.90 and 0.90 v at 108, 115, and 122 Mc respectively. These values correspond to the audio output obtained with a 30 per cent modulated signal of less than 8 microvolts at the receiver antenna terminals (Fig. 7) and are so low that they can be ignored. These tests were repeated using unshielded interconnecting power cables with the NARCO equipment, and the noise meter output increased to 1.45, 1.45 and 1 50 v at 108, 115 and 122 Mc respectively. These values, corresponding to a radio frequency input of about 12 microvolts (Fig 7), are of no consequence.

Ryan Navion

Fig. 40 shows the VHF receiver installation tested in a Ryan Navion. The NARCO receiver-tuner is at the left end of the instrument panel. The omniconverter and power supply unit, not visible, were mounted between the instrument panel and the firewall.

Noise meter readings were 0.18, 0.15 and 0.18 v at 108, 115 and 122 Mc respectively. These readings are too low for consideration. Similar results were obtained with the portable receiver assembly, Fig. 38, located in the front and rear seats of the Navion.

CONCLUSIONS

It is concluded that as far as ignition noise is concerned, any convenient location may be used for the VHF receiver equipment in Piper Cruiser, Stinson Voyager, Ryan Navion and similar aircraft. The routing of the power cable and output leads is not critical, particularly if shielded leads are used. It is probable that in any installation, noise picked

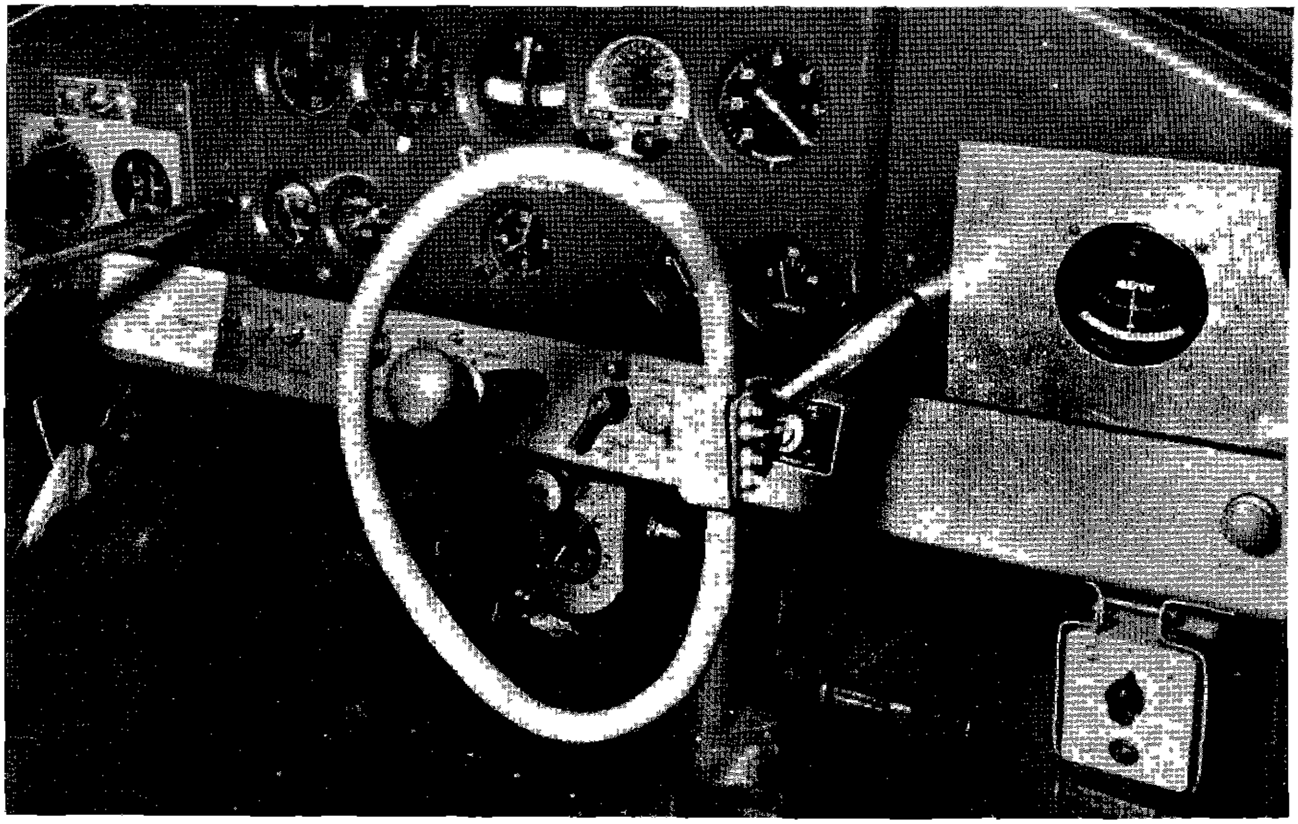


Fig 39 Stinson Voyager Receiver Installation

up by the antenna will be much greater than that due to receiver placement

STAGE IV

ELECTRICAL MOCK-UP

Stage IV of the work program involved the construction of a full-scale model of a typical light aircraft electrical system It was designed to facilitate laboratory studies of various methods for reducing ignition interference in the VHF receiving system

MOCK-UP DESCRIPTION

General

Fig 41 is a photographic view of the completed electrical mock-up of a light aircraft electrical system. It consists essentially of a six-cylinder aircraft engine and electrical system in a cowling mounted on a semi-portable tubular steel frame For convenience in moving, the front end is equipped with two 15 inch rubber tired wheels An electric motor and pulley system is used for driving the engine during tests An instrument panel, containing oil pressure, oil temperature, engine speed and battery charge-discharge indicators, and an ignition switch (located in back of the firewall) simulate a normal aircraft installation A shelf is provided at the rear of the frame for receivers and equipment, and a bracket for VHF antennas is located immediately above the equipment shelf Overall dimensions of the mock-up are 7 feet 8 inches long, 6 feet high, and 3 feet 4 inches wide Two men can easily move the entire assembly for short distances

Engine and Drive System

The aircraft engine used on the mock-up is a Lycoming 0-435-2 six-cylinder engine, enclosed by a conventional metal cowling

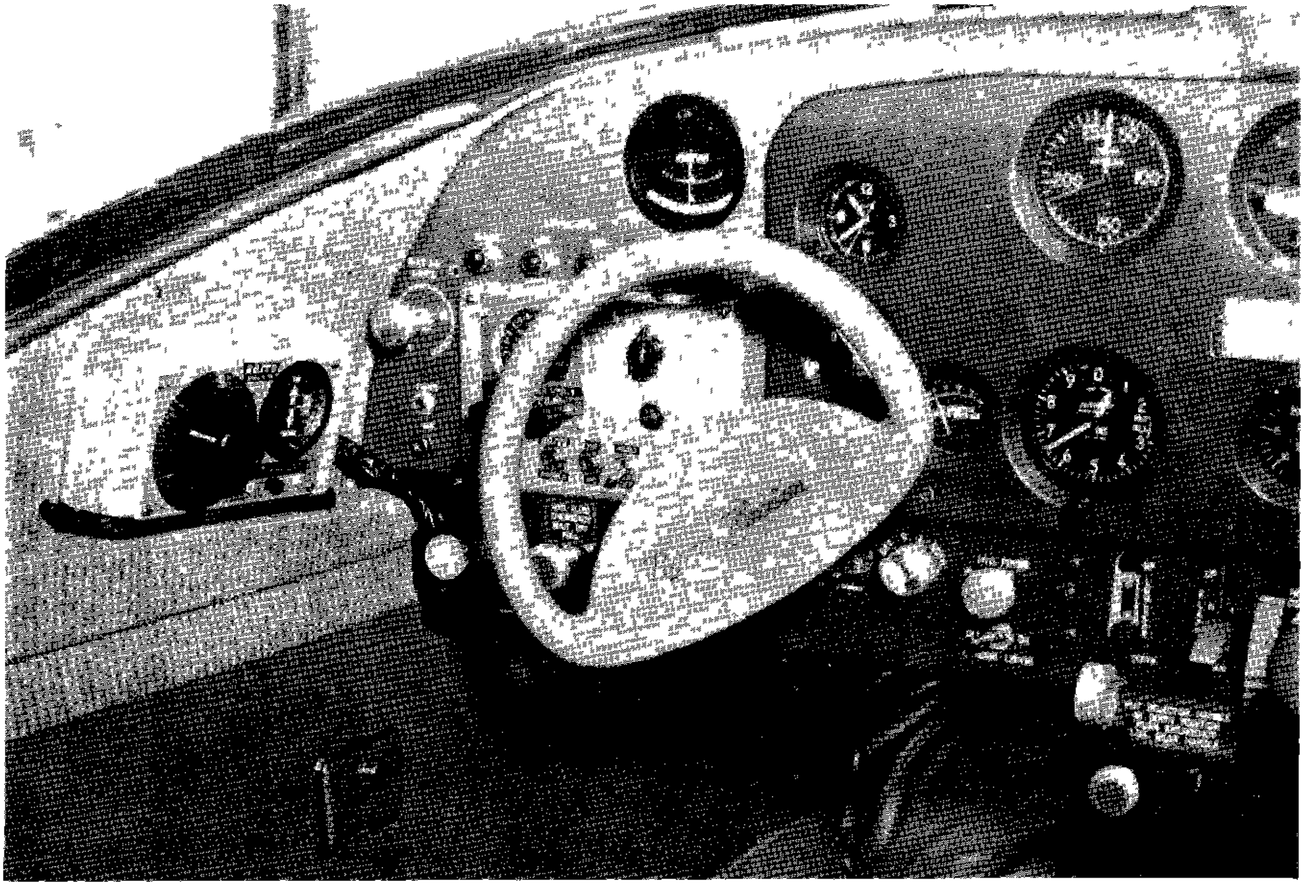


Fig 40 Ryan Navion Receiver Installation

and firewall A 3-hp 3-phase, 220 v, 1,800 rpm electric motor is provided for driving the aircraft engine The Lycoming engine was modified by removing certain parts to reduce driving-power requirements The propeller reduction gears were replaced by a three-fourths inch shaft, to be driven by the electric motor The pistons, connecting rods, cam followers and push rods were removed The valves were sealed, cylinder bases welded closed, and all cylinders connected with tubing to a central point for connection with a pressurized line in order to control pressure in the firing chambers

Table III lists the pulleys, taper bushings and belts provided to obtain engine speeds between 520 and 2,700 rpm as indicated in Table IV

Electrical System

A schematic diagram of the mock-up electrical system is given in Fig 42 Mechanical arrangements are such that electrical components such as generators, voltage regulators, ignition harness, spark plugs

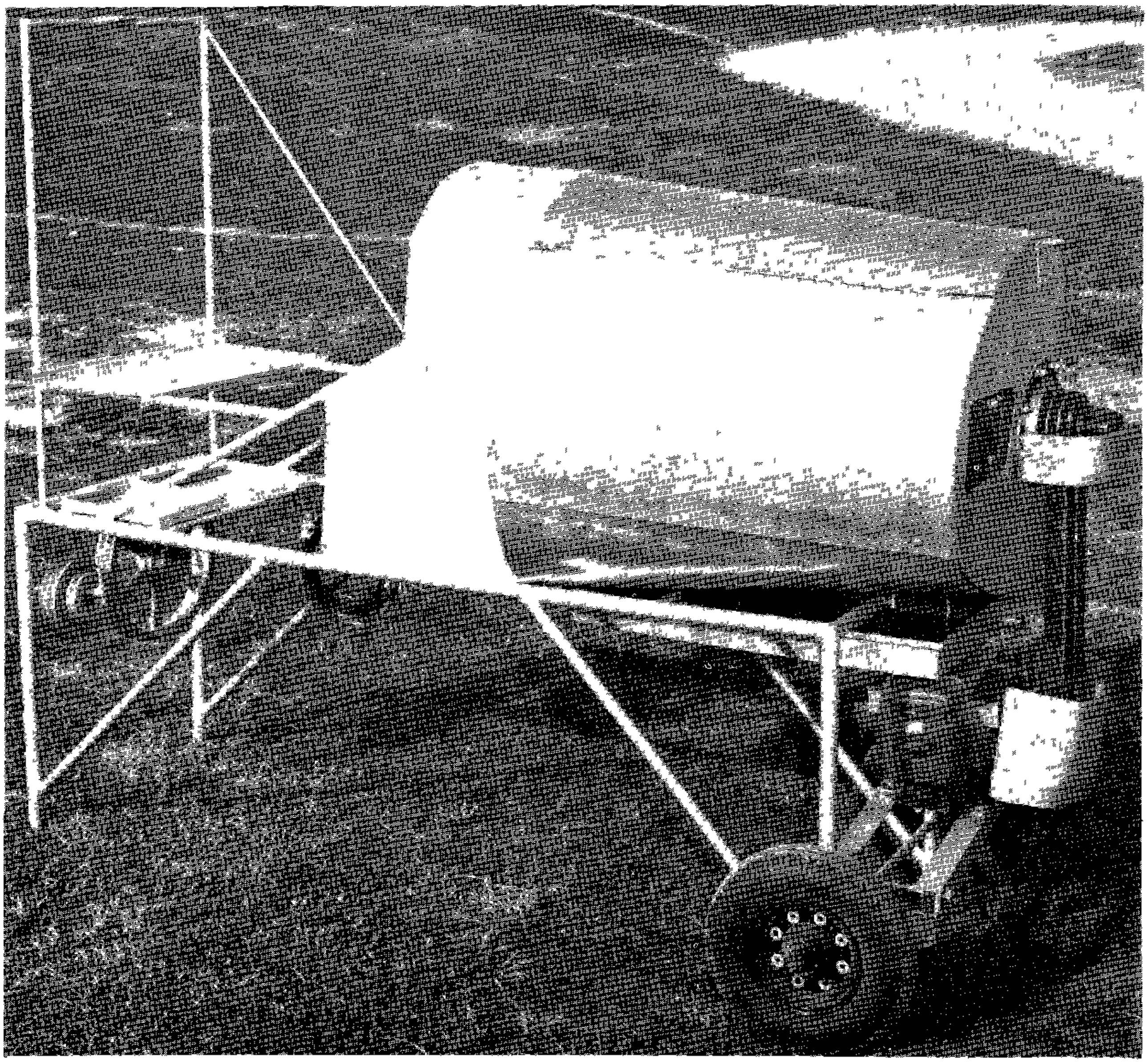


Fig 41 Electrical Mock-Up

and magnetos can be replaced easily and quickly The following replaceable accessories are provided unshielded, shielded, and resistance-wire ignition harness, unshielded, shielded and resistance spark plugs, Delco 1101876 and Eclipse 310 generators, Delco-Remy Voltage regulator, Autolite 23,742 Ammeter, 12 v storage battery, AC 7 ignition switch, and Bendix Scintilla SF6LN8, Eiseman LA4 and Eiseman LM4 magnetos

TABLE III

Mock-Up Engine Drive Accessories

2	Browning,	2TB44 Pulleys (4 4 in D)
1	Browning,	2TB56 Pulley (5 6 in D)
1	Browning,	2TB66 Pulley (6 6 in D)
1	Browning,	2TB154 Pulley (15 4 in D)
1	Browning,	P1 Taper Bushing (3/4 in shaft)
1	Browning,	P1 Taper Bushing (1 in shaft)
1	Browning,	Q1 Taper Bushing (3/4 in shaft)
2	Browning,	2B68 Belts
2	Browning,	2B85 Belts

STAGE V

IGNITION SYSTEM STUDY

Stage V of the work program called for a complete study of ignition systems and an evaluation of all VHF noise sources Tests were made using the aircraft electrical system mock-up described in Stage IV of this report and on aircraft using three different types of engines

MOCK-UP TESTS

Technique

A comprehensive study of all likely sources of VHF ignition interference using the electrical system mock-up was made The ERI-Federal VHF noise meter, described in Stage I of this report, and a Measurements Corp Model 80 Signal Generator were used in measuring the noise voltages at the output of a CAA V-109 antenna mounted on the antenna bracket on the mock-up several feet behind and above the engine The input of the noise meter was connected to a coaxial switch, so that it could quickly be switched to the antenna for noise measurement, and to the signal generator, for calibration

The right magneto on the mock-up was modified by paralleling all six high-tension output terminals, so that the six impulses obtained in one magneto cycle could be fed to one spark plug This was done so that each impulse would be involved with the same size spark gap and the same length of ignition lead, and to expedite measuring procedure The top spark plug on the number one cylinder was connected to the paralleled magneto output

The lower spark plug on the number one cylinder was loosened to permit air to escape after the system was connected to an air pressure system supplying a pressure of 100 psi By this means fresh air was forced through the firing chamber and the ozone content reduced Pressurizing the cylinder resulted in an increase of about 9 db in VHF noise level However, even with the air circulating, there was still a gradual reduction in noise intensity after the ignition was turned on Therefore, all comparative noise measurements were made after approximately the same elapsed time of magneto operation

All noise meter readings were taken at a frequency of 115 Mc, with the engine operating at approximately 2,000 rpm

Bonding Study

In the electrical system mock-up of Stage IV of this report, the magneto grounding wires, generator wiring, and oil-temperature capillary tube all pass through one hole in the firewall The oil pressure line and tachometer shaft each pass through separate holes Arrangements were made to bond these items and the shielding on the wires to the frame by soldering them to a two-inch copper disc bolted to the firewall

Noise-level measurements made with the noise meter were identical before and after the bonding operation The cowling was closed and an Autolite automotive resistor spark plug was in use at the time the measurements were made

Generator Study

Two types of generators were tested on the mock-up These were a Delco Type 1101876 and an Eclipse Type 310 A switch was provided in the generator field circuit to permit (1) normal operation with the voltage regulator, (2) voltage regulation by means of an external rheostat, and (3) making the generator inop-

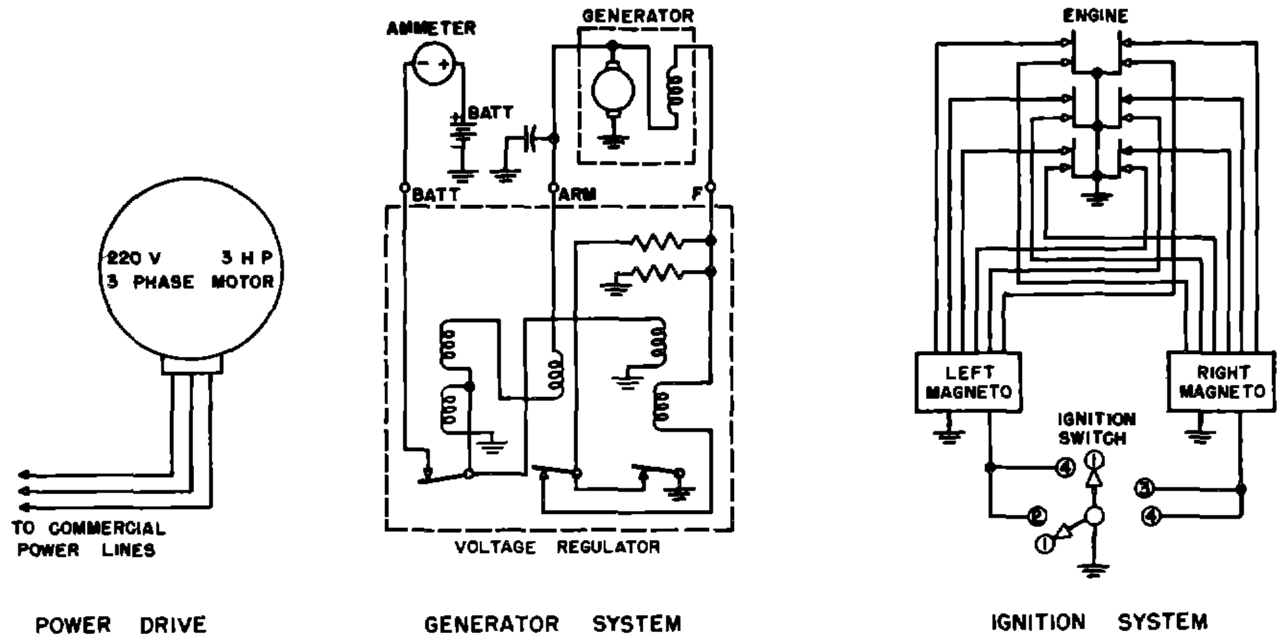


Fig 42 Mock-Up Electrical System

erative

Noise measurements were made with the cowling open and the ignition system turned off Neither generator produced sufficient noise to change the ambient noise reading, which was equivalent to continuous wave input of 0 16 microvolts to the noise meter, unless the field switch was in the voltage regulator position It was found that arcing at the voltage regulator contacts caused a reading on the noise meter equivalent to a continuous wave input of 1 0 microvolts Shunting the voltage and current regulator points to ground with 680 $\mu\mu$ f condensers within the regulator unit reduced the VHF noise level by 9 2 db Closing the cowling virtually eliminated VHF noise produced by the regulator contacts

Magneto Study

The VHF noise levels obtained with three types of magnetos were measured with the ERI-Federal VHF noise meter The magnetos were modified so that all firing impulses would appear at all of the high-tension output terminals The tests were made with the magneto mounted on the right side of the engine and connected to a resistor spark plug in the number one cylinder The spark plug was modified by shorting its points so that it would not contribute to the noise level All measurements were made with the cowling open

Noise meter readings equivalent to the following audio frequency continuous wave inputs were obtained with the following magnetos. Bendix-Scintilla SF6LN8, 24 5 microvolts, Eiseman LM4, 67 microvolts, and Eiseman LA4, 74 microvolts Thus, there is a difference of about 10 db between the several magnetos tested

Noise-Suppressing Accessories

The noise meter was then used in making comparative measurements of the VHF noise reduction obtained with the following noise-reducing devices on the mock-up resistance ignition wire (Titeflex 165 ohms per foot), resistor spark plugs (Autolite automotive), combination of resistance wire and plugs, and shielded ignition system (B G Shielded spark plugs and Titeflex shielded ignition harness) Initially, noise measurements were made using a conventional ignition system with no suppressing devices to establish its noise level A series of tests was made with the cowling open and another with the cowling closed Results obtained are given in Table V

TABLE IV

Mock-Up Engine Speed Data

ENGINE RPM	SPEED RATIO Motor/Engine	ENGINE PULLEY	MOTOR PULLEY	BELT
520	0 289	2 TB 44	2 TB 1 54	2 B 85
662	0 368	2 TB 56	2 TB 1 54	2 B 85
770	0 428	2 TB 66	2 TB 1 54	2 B 85
1200	0 666	2 TB 44	2 TB 66	2 B 68
1415	0 786	2 TB 44	2 TB 56	2 B 68
1525	0 848	2 TB 56	2 TB 66	2 B 68
1800	1 000	2 TB 44	2 TB 44	2 B 68
2285	1 270	2 TB 56	2 TB 44	2 B 68
2285	1 270	2 TB 66	2 TB 56	2 B 68
2700	1 500	2 TB 66	2 TB 44	2 B 68

Note Use Accessories indicated in Columns 3, 4 and 5 to obtain engine speeds of Column 1

TABLE V

Test Data on Noise-Suppressing Accessories

Noise Suppression Used	Noise At Antenna Terminals							
	Mockup, Cowling Open		Mockup, Cowling Closed		Stinson Voyager		Piper Cruiser	
	Microvolts	db	Microvolts	db	Microvolts	db	Microvolts	db
None	1,100	0	16 6	0	56 5	0	24 5	0
Resistance Wire	440	-7 9	10 9	-3 6	400	-3 0	17 5	-2 9
Resistance Spark Plugs	223	-13 9	5 3	-9 9	320	-4 9	4 3	-15 1
Resistance Wire & Plugs	125	-18 9	3 4	-13 8				
Shielded Ignition	6	-45 2	0 18	-39 3	0 8	-37 0	0 8	-29 0

Notes

(1) Microvolts above is cw input to ERI-Federal Noise Meter required for same output reading as obtained with noise

(2) db values given are relative, the 0 db value for each test is different

(3) Noise level measured on Ryan Navion, as supplied with shielded-ignition system, was 17 Microvolts

AIRCRAFT TESTS

Measurements were made on the various noise-suppressing devices installed on three aircraft with three different types of engines The tests were made on the ground, with the same procedure as was used for similar tests on the mock-up

Stinson Voyager (Franklin Engine)

Tests were made on the Stinson Voyager airplane with the ERI-Federal VHF noise meter connected through 30 feet of RG-8/U cable to a CAA V-109 antenna on the aircraft The antenna location was the same as that used in Flight 4 in Stage II of this report, and is shown in Figs 29 and 32 The test data obtained is recorded in Table V

Piper Cruiser (Lycoming Engine)

Tests were made on the Piper Cruiser airplane with the ERI-Federal VHF noise meter connected through 30 feet of RG-8/U cable to a CAA V-109 antenna on the aircraft The antenna location was the same as that used in Flights 1 and 2 in Stage II of this report, and is shown in Figs 29 and 30 The test data obtained is recorded in Table V

A peculiar condition was observed on the Piper Cruiser When the shielded ignition system of noise suppression was used, a noise peak of about 3 2 microvolts at 114 Mc was observed when both magnetos were operating simultaneously, but this was reduced to about 0 8 microvolts when either magneto was operating alone This was found to be caused by a resonant condition in the leads to the ignition switch It was found that disconnection of the safety ground wire, leading from the magneto grounding switch to the engine, corrected this condition, as did the by-passing of each switch terminal to ground with 100 μμf condensers Presumably bonding the ground wire to the fuselage at a number of points also would have corrected the trouble although it was noted that bonding at only one point was of little value

Navion (Continental Engine)

The only noise-suppression system tested on the Navion airplane was the shielded ignition system with which the aircraft was already equipped The antenna installation on this aircraft was that given in Fig 29 for Flight 9, of Stage II of this report The VHF noise level was found to be of no consequence, as indicated in Table VI

CONCLUSIONS

It is concluded that the ignition system is the cause of most of VHF noise on light aircraft Arcing at the spark plug gaps seems to be the source of VHF interference, and the ignition leads between the spark plugs and magneto radiate the noise energy created thereby

It was found that the best method of VHF noise reduction was shielding the ignition system, but that satisfactory performance could be obtained with resistance spark plugs By the use of resistance spark plugs, VHF noise at the antenna terminals was reduced 9 9 db with the Lycoming engine on the mock-up, 15 1 db with the Lycoming engine on the Piper Cruiser, and 4 9 db with the Franklin engine on the Stinson Voyager

STAGE VI

FLIGHT TESTS

The Stage VI work program called for flight tests with three aircraft to evaluate the performance of VHF noise-suppression systems, and determine the signal-to-noise ratios obtained These flight tests with four types of airplanes were made in Stage II of the work program and are described completely in that section of this report However, signal-to-noise ratio measurements, made on only the required three aircraft, not reported in Stage II, will be described here

SIGNAL-TO-NOISE RATIO TESTS

Technique

Signal-to-noise ratio measurements were made with the best VHF antenna installations on the Piper Cruiser, Stinson Voyager and Ryan Navion airplanes, using the shielded ignition method of noise suppression The tests were made at the double course-width distances with the aircraft flying toward and away from the range station An average of the two readings thus obtained was recorded

The ERI-NARCO VHF noise meter was used in making the actual ratio measurements The procedure was to note the relative noise meter output readings obtained with the omnirange station in tune, and with the receiver tuned off any signals present Thus, the ratios obtained are those of the audio voltages at the omnioutput jack of the receiver resulting from residual noise level and the 30 and 10,000 cps modulation of the omnirange station

Piper Cruiser

The signal-to-noise ratio measured on the Piper Cruiser installation of Flight 2 (Figs 29 and 30) was 7 4 db

Stinson Voyager

The signal-to-noise ratio measured on

the Stinson Voyager installation of Flight 6 (Figs 29 and 32) was 5 4 db

Ryan Navion

The signal-to-noise ratio, measured on the Ryan Navion installation of Flight 8 (Figs 29 and 33) was 7 9 db

CONCLUSIONS

The signal-to-noise ratios obtained by the method described give a pessimistic picture of actual conditions inasmuch as they were made at a point preceding the noise limiters in the receiver, and the ratios obtained are those of noise peak voltages to the 30 and 10, 000 cps modulation on the VHF omnirange station The measurements indicate that the signal-to-noise voltage ratio on all three aircraft at the double course-width distance is in the order of two to one

STAGE VII

VHF RADIO INSTALLATION MANUAL

Stage VII of the work program called for the preparation of a simplified instruction manual on the reduction of radio noise and the installation of VHF equipment in light aircraft This manual, entitled "VHF OMNIRANGE RADIO INSTALLATION AND NOISE REDUCTION TECHNIQUES" is included as Appendix I of this report

STAGE VIII

FINAL FLIGHT TESTS

Stage VIII of the work program called for noise-suppression installations on Temco, Luscombe, Ercoupe, Cessna, Bellanca, Beechcraft, Navion, Piper Cruiser and Stinson airplanes, applying the techniques outlined in the VHF radio installation manual The installations were made on the designated aircraft, which were subsequently flight tested The experimental technique used is given under "Flight Tests" in Stage II of this report, which also describes the flight tests and installations made on the Piper Cruiser, Stinson Voyager, Navion and Beechcraft airplanes Additional details are also given in Stage III

An outline of the work done on the remaining aircraft will now be given Table VI is a complete summary of all flight test data, and in some cases duplicates information previously presented Table VII shows flight pattern data not already shown in Table II

FLIGHT TESTS

Ercoupe, Flight 13

The NARCO VRA-1 VHF receiver and associated equipment was installed in a Model 415G Ercoupe The receiver unit was mounted below the center of the instrument panel, and the OBS dial and TO-FROM meter assembly were on an aluminum plate over the right glove compartment opening The power supply and omniconverter units were located on the firewall in the cabin A CAA V-109 antenna was mounted 26 inches behind the windshield on the center line of the aircraft (Fig 43)

Flight 13 was made using the aircraft as supplied without any noise-suppressing devices Unsatisfactory results were obtained due to the high ignition noise level, the course-width doubling at only 25 miles

Ercoupe, Flight 14

Resistance spark plugs were installed on the Ercoupe and Flight 14 was made under conditions otherwise similar to those of Flight 13 Measurements on the ground using the ERI-Federal VHF noise meter revealed that the VHF noise level at the antenna terminals was reduced from 44 to 25 microvolts with the installation of resistance spark plugs

As can be seen from the data for Flight 14, Table VI, and from the antenna patterns in Fig 44, satisfactory results were obtained Greater forward sensitivity indicated in the antenna patterns apparently was not too severe

Luscombe, Flight 15

The NARCO VHF equipment was installed on a Model 8E Luscombe airplane as shown in Fig 45 The controls and indicators were located on the right side of the instrument panel The power supply and modulator units, not visible in the photographic view were mounted on the firewall above the rudder pedals The CAA V-109 antenna location, shown in Figs 43 and 45, was above the cabin, 34 inches behind the windshield

Preliminary flights with the Luscombe,

TABLE VI

Flight Data Summary

Aircraft	Flight	Illustrations, Fig No's	Suppression Used	Test #1			Test #2		Test #3				Test #4		Test #5	Test #6			Test #8								Test #9								Stage VI
				Noise Reduction Volts*			Double Course Width Distance, Miles		20 Mile Course Width, Degrees				Tilt Deflection, Degrees		Readability Limit, Miles	Propeller Modulation Deviation, Degrees			Bearing Error At 20 Miles, Degrees								Bearing Error In 30° Bank, Degrees								Signal To Noise Ratio db
				108 mc	115 mc	122 mc	To	From	North	East	South	West	To	From		1800 rpm	2100 rpm	2400 rpm	N	NE	E	SE	S	SW	W	NW	N	NE	E	SE	S	SW	W	NW	
Piper	1	37, 38, 45	Res Plugs	19	15	16	48	46	25	34	25	39	3	3	53	3	3	15																	
"	2	37,38,39,45	Shielded	05	07	05	49	47	30	30	27	33	15	0	53	3	3	15	-1	1	0	-1	0	0	0	0	45	0	0	1	-6	-45	-6	-45	74
'	3	26, 37, 45																																	
Stinson	4	37, 40, 47	Res Wire	55	46	50	36	34	35	40	40	45	1	1	45	3	0	0																	
"	5	37, 40, 47	Res Plugs	18	15	16	49	46	35	35	34	35	3	15	54	3	0	0																	
"	6	37,40,45,47	Shielded	05	07	06	53	53	30	34	51	37	15	0	56	3	0	0	1	1	2	0	0	1	-1	1	1	1	15	0	-3	-3	-3	-45	54
	7	37, 45, 47	'	05	07	06	43	48	30	37	30	38	15	1	54	15	0	0																	
Navion	8	37,41,45,48	Shielded	03	04	04	48	48	38	39	37	42	15	15	57	0	0	0	0	-1	-1	0	0	0	-1	0	-3	-45	0	3	1	0	-3	-45	79
'	9	37, 45, 48	"	02	02	02	46	44	37	39	38	40	0	0	53	3	0	15																	
	10	37,42,45,48	"	02	02	02	36	37	38	40	38	41	3	3	48	15	15	3																	
Beechcraft	11	37, 43, 45	Shielded	04	04	05	45	46	35	42	35	43	15	15	54	0	0	0																	
'	12	37, 44, 45	"	03	04	04	32	46	34	50	37	41				15	0	15																	
Ercoupe	13	55, 56	None	45	36	30	25	25	40	65	40	75	3	3	37	0	0	0																	
"	14	55, 56	Res Plugs	20	16	14	45	45	29	33	35	33	3	3	55	0	0	0																	
Luscombe	15	55,56,57,58	Res Plugs	16	11	10	47	47	41	41	43	45	3	15	Good At 47 Miles	3	0	0																	
Swift	16	55,56,59,60	Shielded	04	04	04	55	55	38	41	37	40	3	15	62	15	15	0																	
Bellanca	17	55,56,61,62	Def Shield	46	38	30	34	34	45	48	42	50			42	3	0	15																	
	18	55,56,61,62	Shielded	04	04	04	45	45	38	39	38	42	15	15	50	3	0	15																	
Cessna	19	55,56,63,64	Def Shield	45	35	31	35	35	38	36	35	43	3	3	43	3	0	0																	
"	20	55,56,63,64	Shielded	03	04	04	47	47	35	40	35	42	0	0	54	3	0	0																	

* Volts at output of ERI-NARCO VHF noise meter See Fig 7

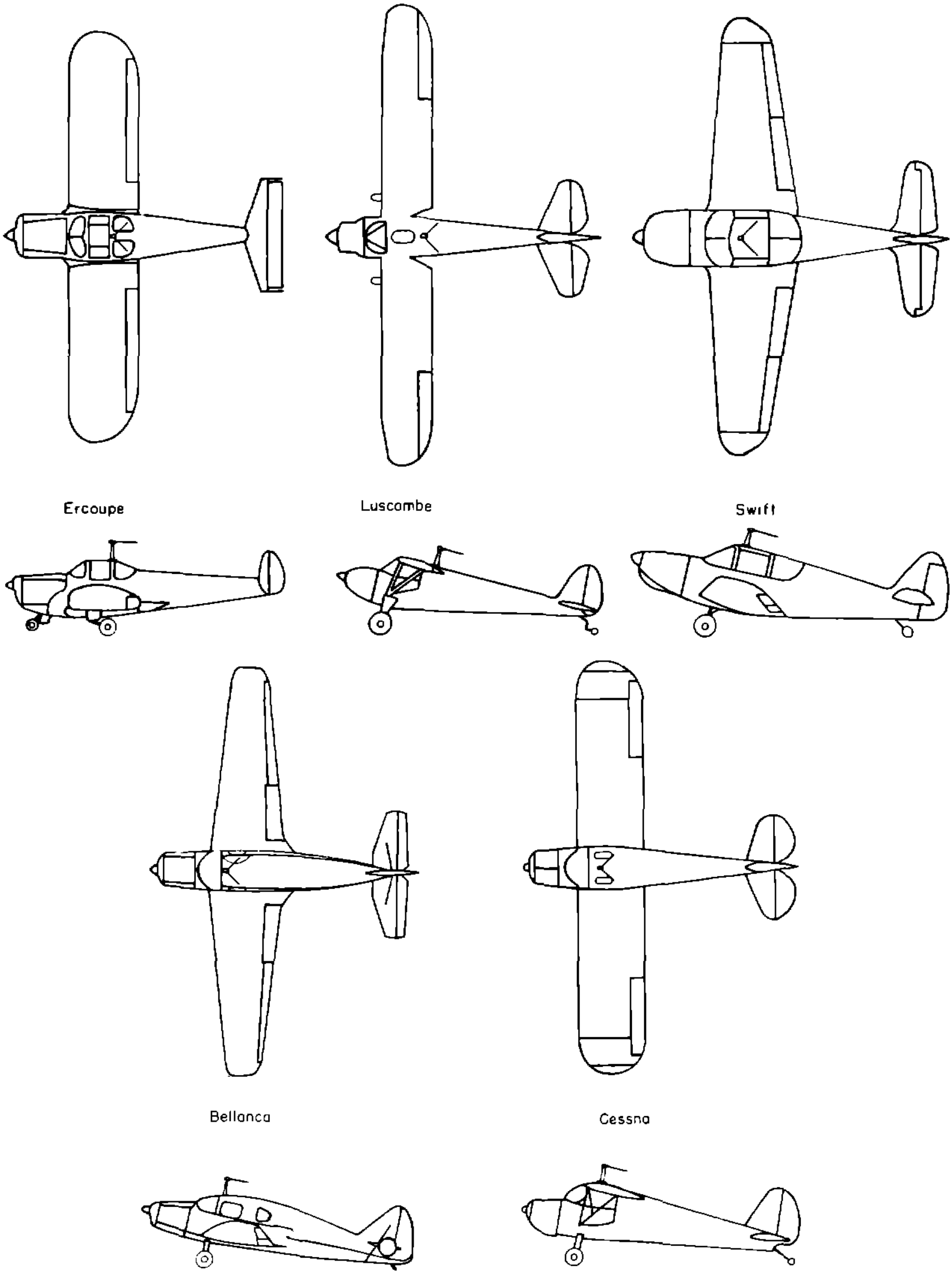


Fig 43 Antenna Locations for Stage VIII Flight Tests

Table VII

Stage VIII Flight Pattern Data

Aircraft	Flight	*Relative Received Voltage At Heading Of								Altitude Feet	Distance Miles	Attenuator db
		0°	45°	90°	135°	180°	225°	270°	315°			
Ercoupe	14	4 40	2 60	1 70	4 20	3 00	3 60	1 90	3 20	1000	15	12
		3 60	2 50	1 60	3 20	2 80	3 20	1 80	3 10	2000	15	12
		4 80	3 80	2 20	4 50	4 70	4 10	2 50	4 50	4000	15	12
Luscombe	15	3 50	3 50	2 90	3 70	2 90	3 50	1 20	2 60	1000	15	12
		2 40	2 40	3 00	2 50	3 00	2 60	3 60	3 50	2000	15	12
		2 90	3 50	3 50	2 40	2 90	2 50	3 40	3 50	4000	15	12
Swift	16	3 80	3 30	1 30	2 40	3 60	3 70	1 20	2 60	1000	15	12
		3 60	3 30	1 70	2 50	3 80	3 10	1 30	2 60	2000	15	12
		2 40	3 10	3 30	3 30	2 70	3 20	3 10	3 30	4000	15	12
Bellanca	18	3 20	3 20	1 60	2 10	2 70	2 20	1 30	2 50	1000	18	12
		4 10	4 40	3 30	3 00	4 40	4 40	2 80	4 30	2000	18	12
		4 60	4 40	4 10	2 40	4 40	4 30	2 80	4 10	4000	18	12
Cessna	20	2 10	1 80	1 40	1 20	1 80	1 50	0 80	1 30	1000	25	12
		3 10	3 20	1 90	3 10	2 40	2 50	1 70	3 10	2000	25	12
		4 00	3 20	2 40	2 40	3 20	2 60	1 30	2 50	4000	25	12

* Volts at output of ERI - NARCO VHF noise meter
Use with Attenuator value and Table 7 to obtain RF input

using no noise-suppression devices, produced results which were almost satisfactory Resistance spark plugs were installed, reducing the noise level at the antenna terminals, as measured on the ground with the ERI-Federal VHF noise meter, from 19 to 1 7 microvolts before Flight 15 was made

Excellent results were obtained in all flight tests See Table VI and Fig 44

Globe Swift, Flight 16

The Globe Swift aircraft used for flight tests was one manufactured by the Globe Company and is of the same type now being made by Temco Fig 47 shows the receiver installation on the Swift Model GC1B Aircraft which was flight tested The receiver unit was mounted below the center of the instrument panel and the OBS and TO-FROM meter assembly were on an aluminum panel over the right glove compartment opening The power supply and omniconverter units were mounted on side structural members above the right rudder controls A CAA V-109 antenna was mounted on the center line over the cabin 11 5 inches behind the windshield, as shown in Figs 43 and 48

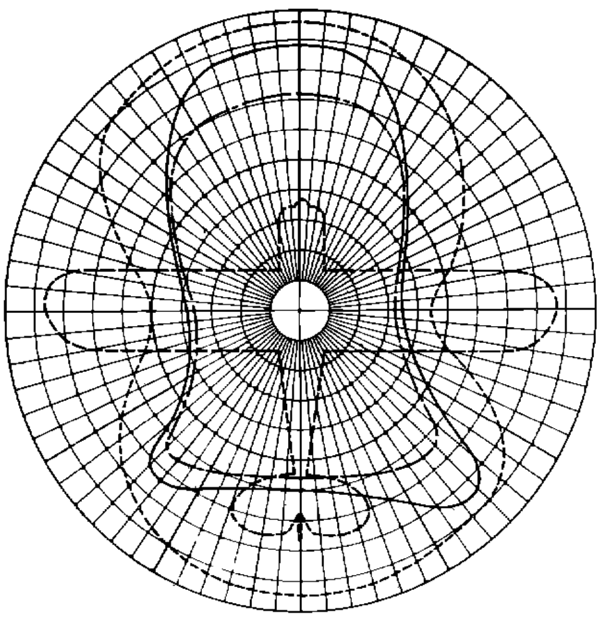
The aircraft was tested with the shielded ignition system as installed at the factory Preliminary noise measurements on the ground indicated that the noise level was low

Excellent results were obtained on all flight tests, the double course-width distance being 55 miles and readability limit 62 miles See Table VI The flight patterns, Fig 44, were almost ideal

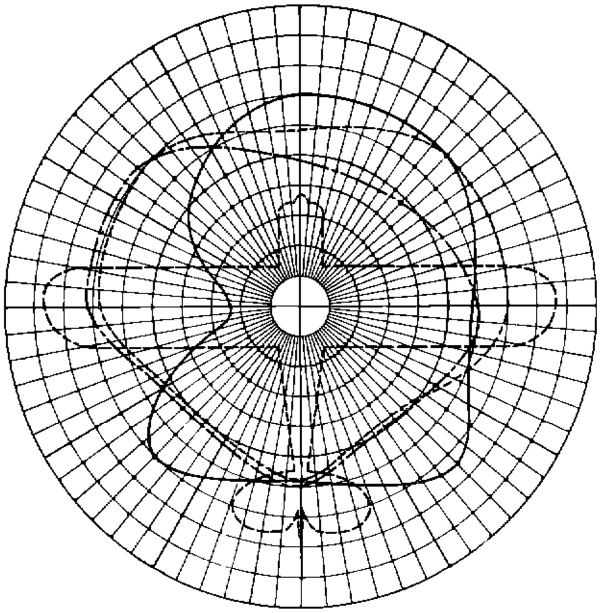
Bellanca, Flights 17 and 18

A Bellanca (Model 14-13-2) airplane with factory-installed shielded ignition system was used in Flights 17 and 18 Fig 49 shows the VHF installation The receiver unit was mounted below the instrument panel, and the OBS dial and TO-FROM meter assembly were mounted on an aluminum panel over the glove compartment opening The power supply and omniconverter units were placed on the floor at the right in a temporary manner A CAA V-109 antenna was located above the cabin just behind the windshield as shown in Figs 43 and 50

Preliminary measurements on the ground revealed a very high VHF noise level The DI fluctuated wildly during the initial

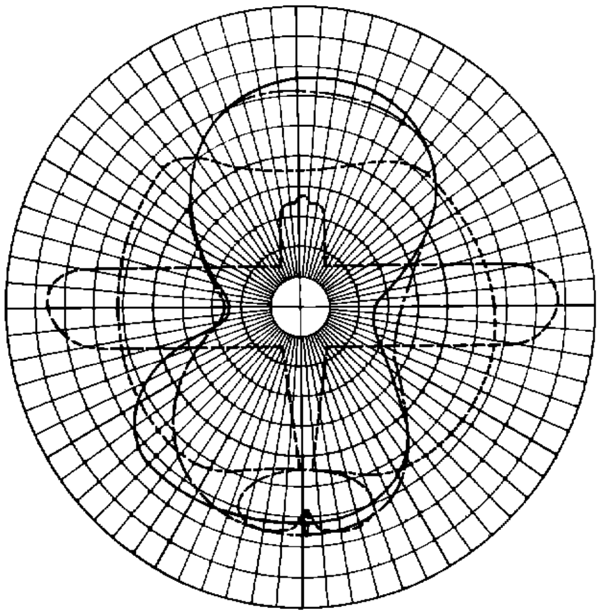


ERCOUPE FLIGHT 14
V-109 ANTENNA OVER CABIN



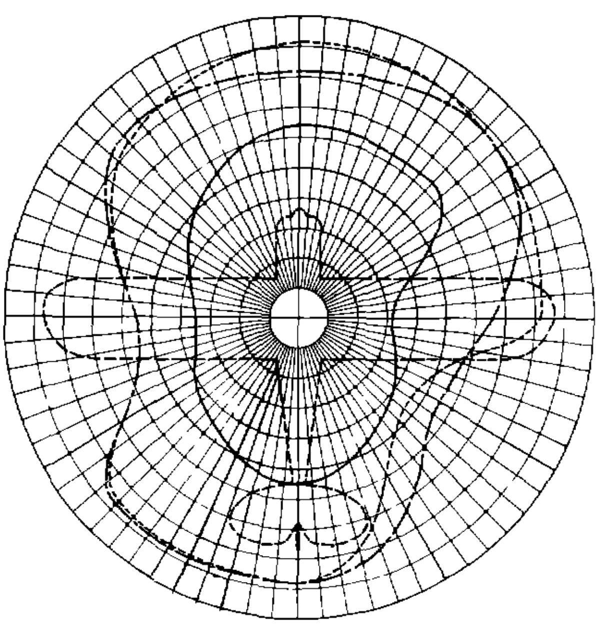
LUSCOMBE FLIGHT 15
V-109 ANTENNA OVER CABIN

ALTITUDE
1000 FT ————
2000 FT —·—·—
3000 FT ----------



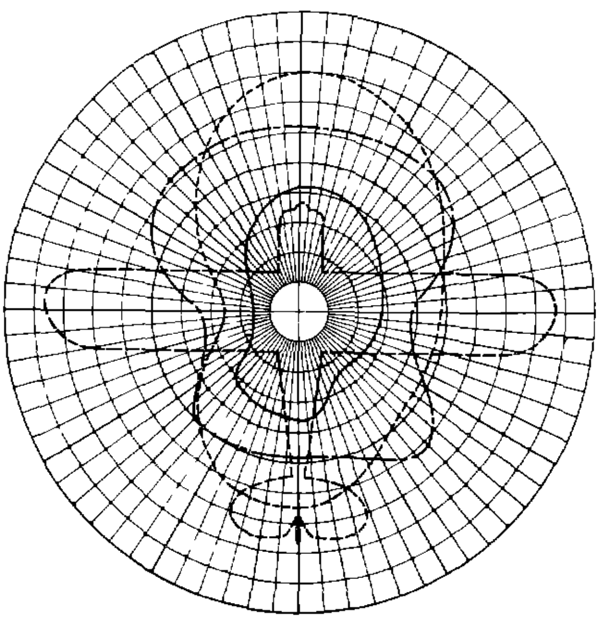
SWIFT FLIGHT 16
V-109 ANTENNA OVER CABIN

Fig 44 Stage VIII Flight Patterns



BELLANCA FLIGHT 18
V-109 ANTENNA OVER CABIN

ALTITUDE
1000 FT ————
2000 FT —-—-—
3000 FT --------



CESSNA FLIGHT 20
V-109 ANTENNA OVER CABIN

Fig 44 (Continued)

warm-up, however, Flight 17 was made, but with the generally unsatisfactory results indicated in Table VI

An investigation of the shielded ignition system revealed many loose connections Loose packing nuts at both the magneto and spark plug ends of the ignition wiring were found The entire shielded ignition system was gone over carefully and repaired Measurements on the ground with the ERI-Federal VHF noise meter revealed that the noise level was reduced to 3 3 microvolts Flight 18 was then made The flight data, Table VI, reveals that the double course-width distance increased from 34 to 45 miles as a result of the repairs and that an acceptable installation was obtained

Cessna, Flights 19 and 20

The receiver installation shown in Fig 51 was used on a Model 140 Cessna aircraft for Flights 19 and 20 The receiver unit was mounted behind a meter opening at the upper right of the instrument panel The OBS dial and TO-FROM meter assembly were mounted on an aluminum panel over the left glove compartment opening The omniconverter and power supply units were temporarily mounted on the floor between the rudder pedals A CAA V-109 antenna was mounted on the center line of the aircraft above the cabin 10 inches behind the windshield as shown in Figs 43 and 52 Flight 19 was made before any changes were made in the factory-installed shielded ignition system, even though preliminary ground measurements indicated a high VHF noise level As can be seen from the data in Table VI, poor results were obtained

Inspection of the shielded ignition system revealed loose shield packing nuts at the spark plugs and magneto The shielded system was gone over carefully and all loose connections secured, after which the noise level, as measured with the ERI-Federal VHF noise meter, was reduced to 1 7 microvolts at the antenna terminals

Flight 20 was made after the aforementioned repairs were made on the shielded ignition system The data in Table VI reveals that excellent results were obtained, the double course-width distance having increased from 35 to 47 miles The antenna patterns, Fig 44, show rather small lobes to the rear, but this did not prevent the obtaining of acceptable

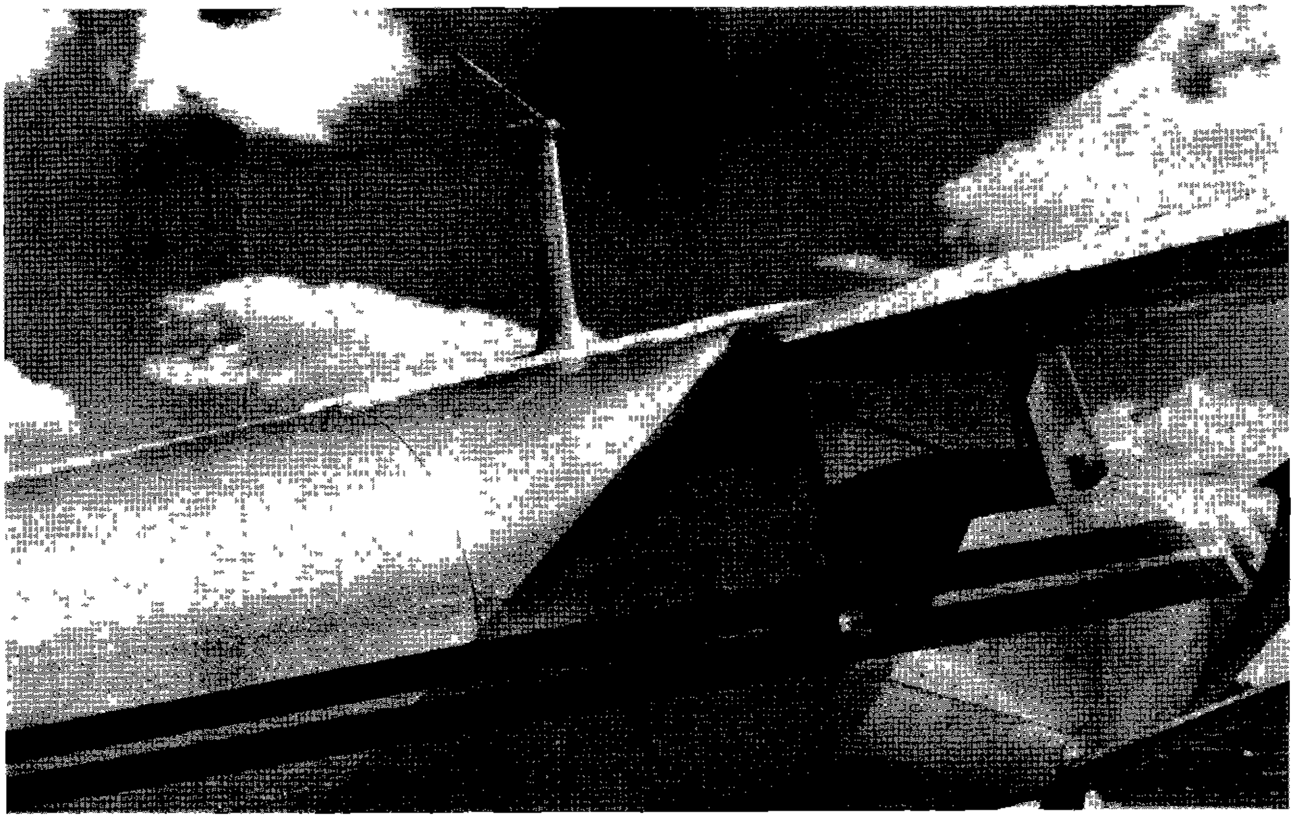


Fig 45 V-109 Antenna on Luscombe

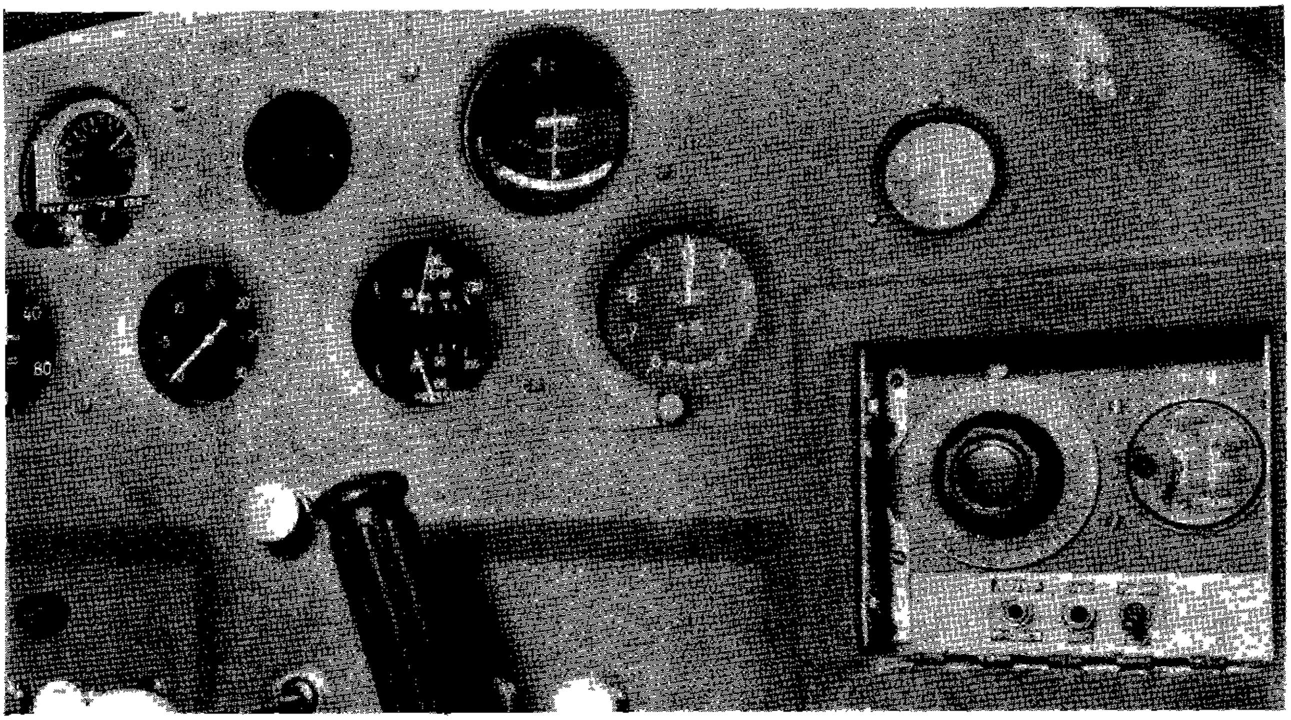


Fig 46 Luscombe Receiver Installation

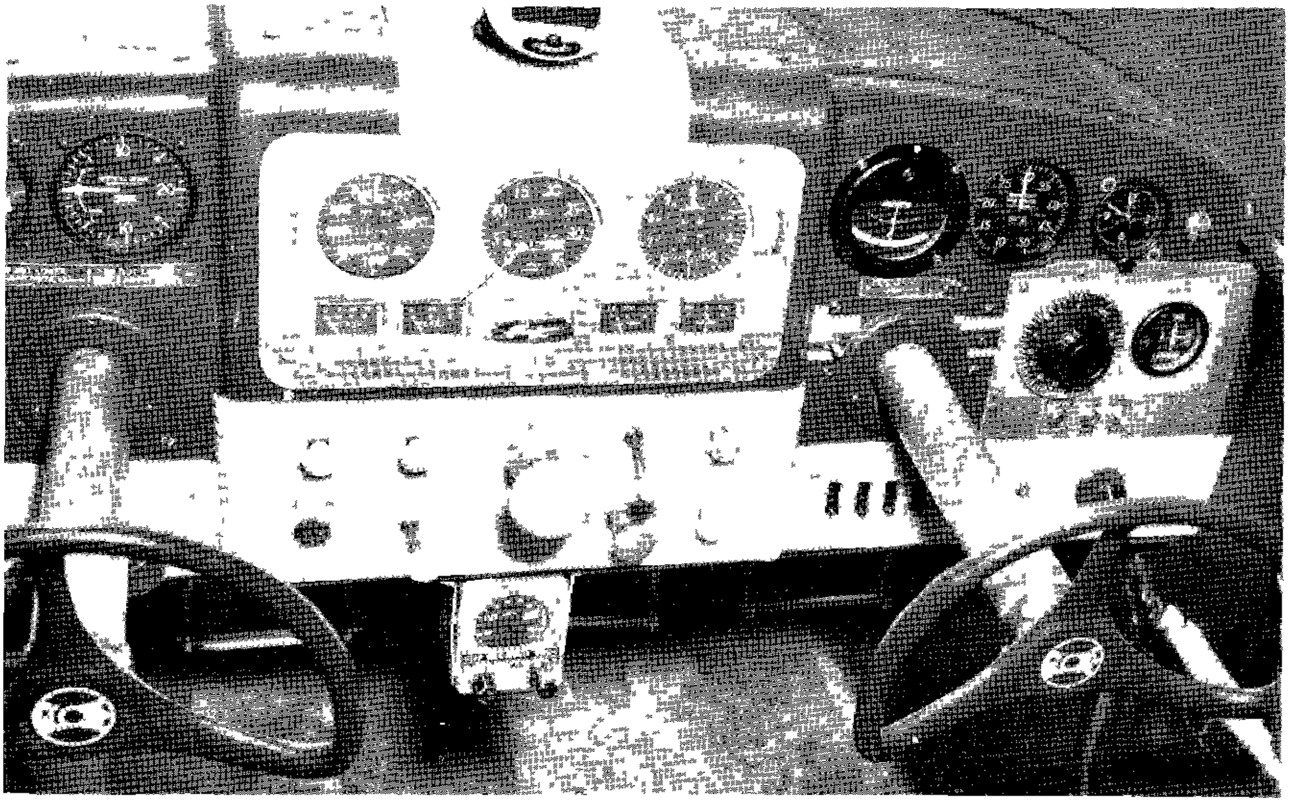


Fig 47 Swift Receiver Installation

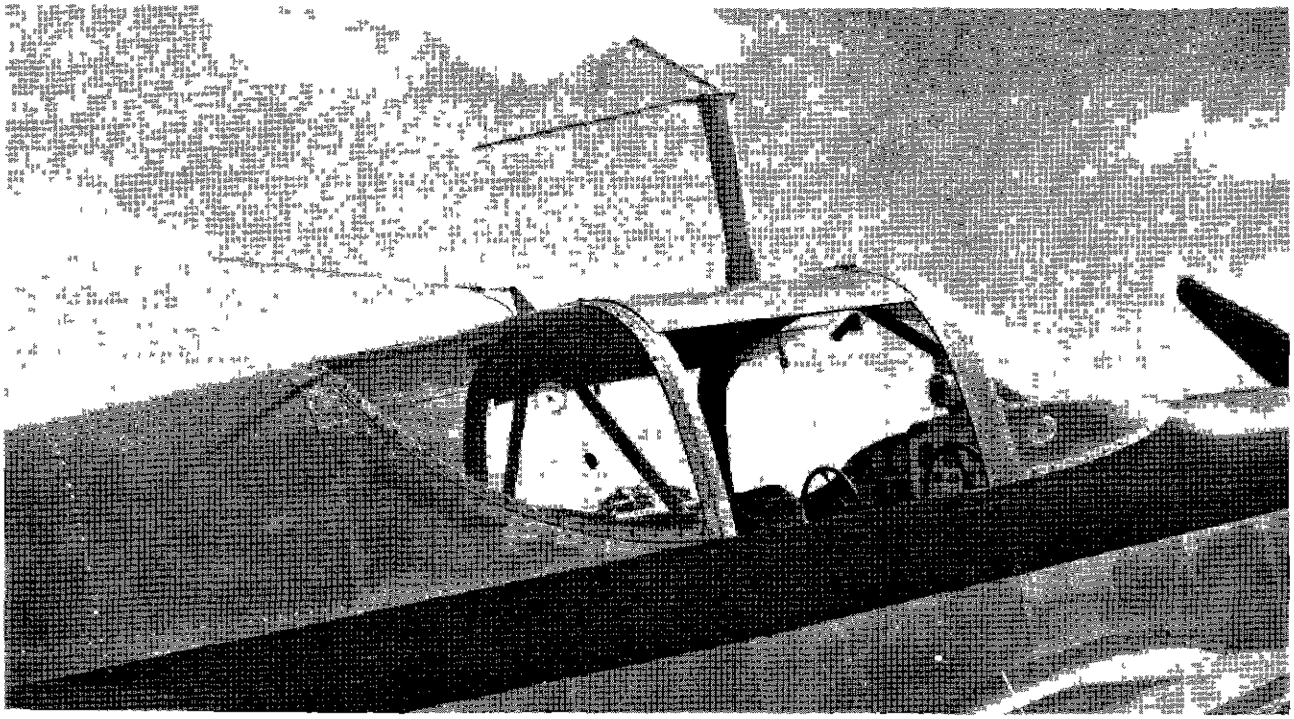


Fig 48 V-109 Antenna on Swift

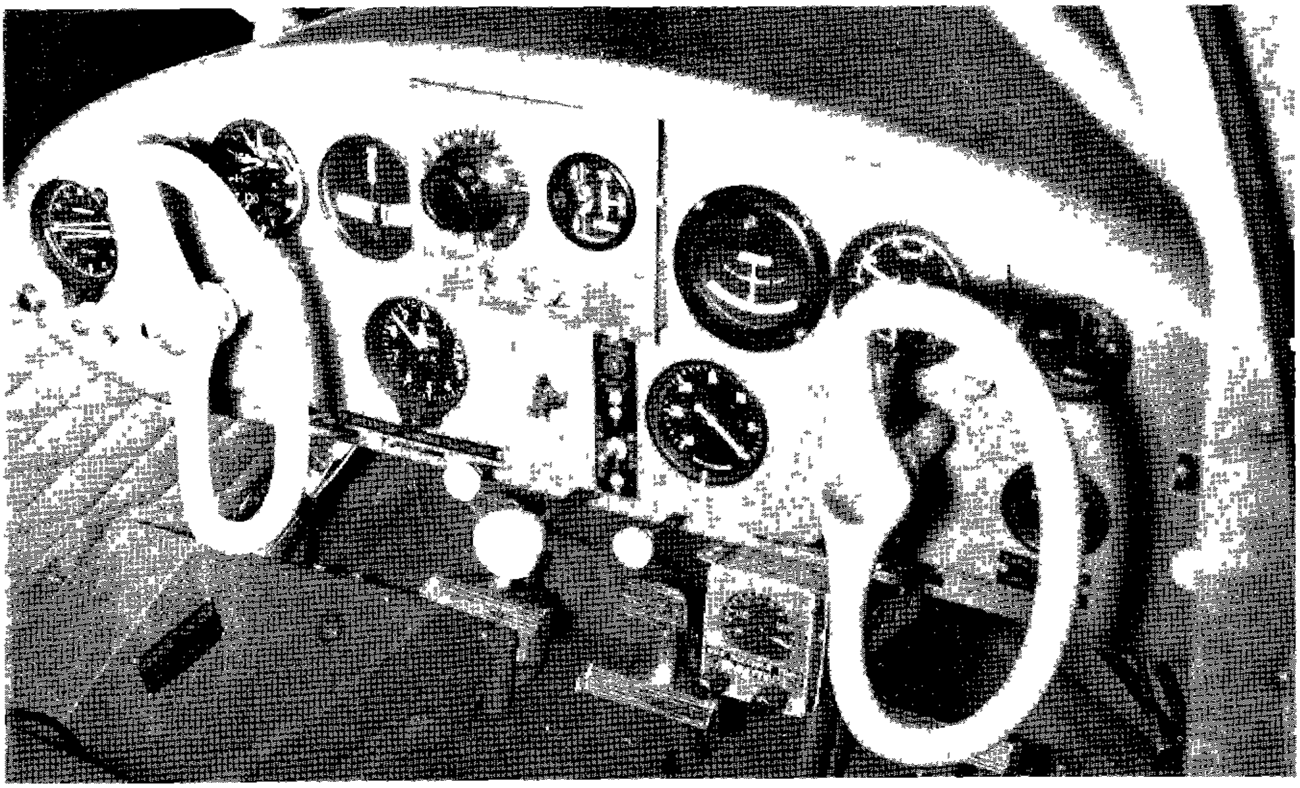


Fig 49 Bellanca Receiver Installation

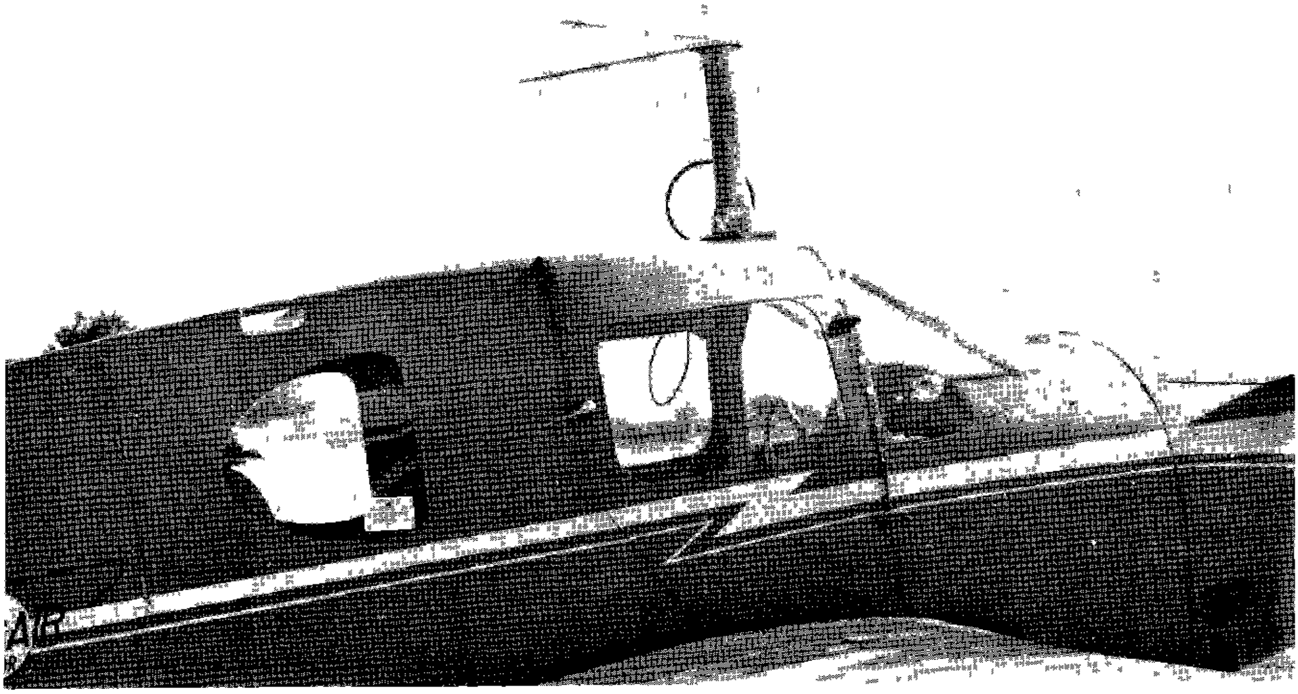


Fig 50 V-109 Antenna on Bellanca

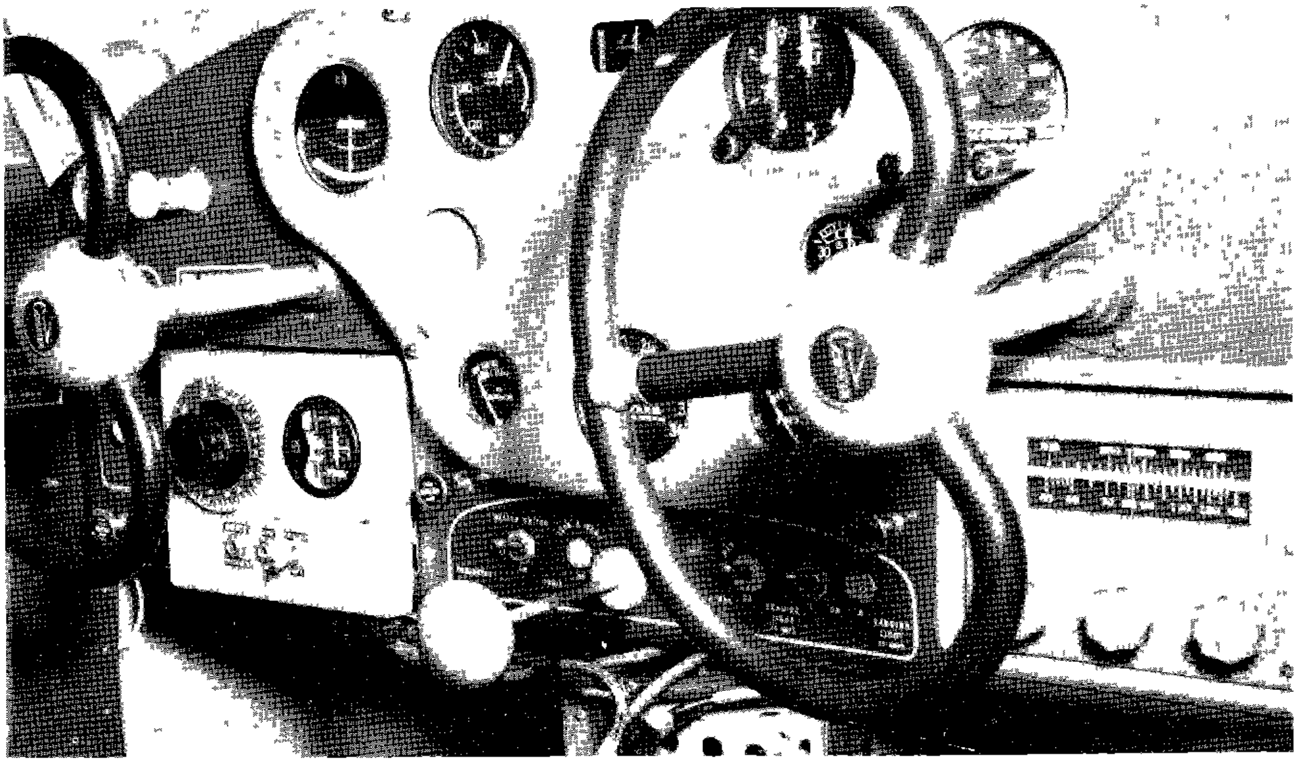


Fig 51 Cessna Receiver Installation

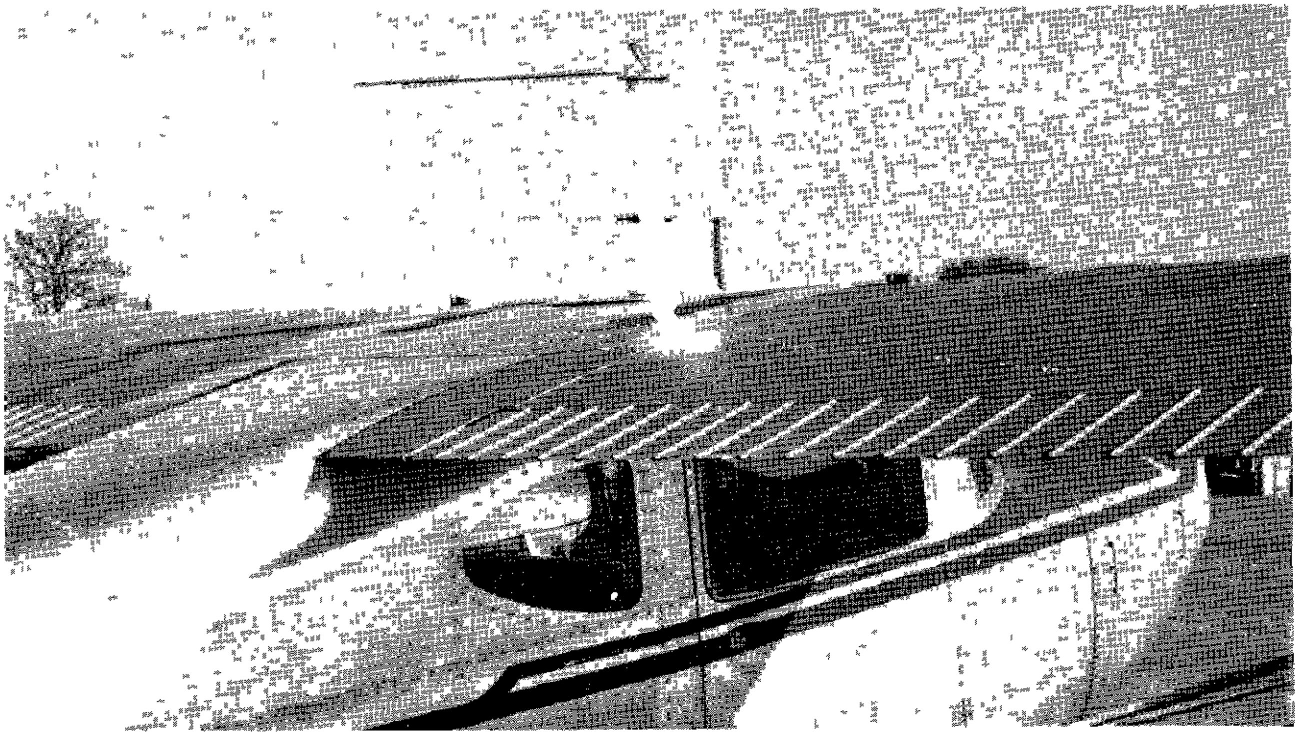


Fig 52 V-109 Antenna on Cessna

flight performance

CONCLUSIONS

The flight tests reveal that satisfactory VHF installations can be made on light aircraft by following the recommendations outlined in the VHF radio installation manual of Stage VII A good V antenna location on most light aircraft is over the forward part of the cabin on the center line of the aircraft Of the nine aircraft tested, on only one was a better antenna location found (tail-cap location of the Navion)

The exact location of receiver components is not critical In none of the nine aircraft was it found necessary to change the receiver location to obtain satisfactory noise reduction

Employment of resistance spark plugs will provide satisfactory ignition noise reduction in most aircraft, provided the VHF receiver has properly designed noise limiter circuits However, the best system of noise suppression appears to be the shielded ignition system A disadvantage of shielded ignition systems is that they are ineffective unless good electrical and mechanical connections are initially made and maintained

Mention was made of near-acceptable performance being obtained on the Luscombe without any noise-suppressing accessories This was undoubtedly due to such details as the good overlapping contact made along the edges of the cowling cover (Fig 53)

Fig 53 Luscombe Cowling

APPENDIX I

VHF Radio Installation Manual for VHF Omnirange Radio Installation and Noise Reduction Techniques

INTRODUCTION

This VHF radio installation manual is a brief presentation of equipment installation and radio noise-reduction techniques. Antenna locations giving good signal and good omnicourse characteristics are shown for nine types of light aircraft The radio equipment location, which is comparatively noncritical, has been omitted

VHF NOISE REDUCTION IN LIGHT AIRCRAFT

The General Problem

Noise in VHF (very high frequency) radio receivers is produced by electrical arcs in the proximity of the receiving antenna Thus on aircraft the continuous arcing or sparking that necessarily occurs at the spark plug points causes an equally continuous noise in the VHF receiver Other electrical equipment can also cause VHF noise, but it has been experimentally determined that almost all VHF interference on light airplanes is due to arcing at the spark plugs

The VHF noise produced by this arcing is radiated into surrounding space by the wires connected between the spark plugs and magneto The ignition wires perform the same function as far as noise is concerned, as does the transmitting antenna at a radio station Thus, the VHF receiving antenna on the aircraft picks up the noise radiated by the ignition wires

The general problem, then, is to place the VHF receiving antenna at a point on the airplane where it will have the greatest possible sensitivity for desired signals and a minimum response to noise radiated by the ignition system, and to do everything possible to reduce radiation at its source When these requirements are met, excellent performance can be expected from VHF omnirange receiver installations up to slightly beyond line-of-sight distances from the sending stations (about 45 miles, at an altitude of 1,000 feet and up to 80 miles at higher altitudes)

Antenna Location

The best location for the VHF V receiving antenna on most small aircraft is over the forward part of the cabin The antenna should be mounted so that the apex of the V points forward, and so that the plane of the V is horizontal in level flight A list of some antenna locations on a number of popular small aircraft giving the distance back of the windshield in inches follows

Piper	7
Swift	11
Ercoupe	26
Bellanca	4
Stinson	13
Luscombe	34
Cessna	10
Beech Bonanza	35
Navion	6 to 10 in above tail cap (With CAA Approval)

Figs 54, 55 and 56 are outlines of these airplanes indicating the antenna locations In applying this information in practice it is important to see that other metal protrusions, such as antennas, on the airplane are at least two feet away from the VHF V The lead-in between the antenna and the receiver should be of the type recommended for use with the particular equipment involved, and run by as short and direct a route as conveniently possible

Resistance Spark Plugs

On most airplanes having unshielded ignition the noise radiated by the ignition system can be reduced to a satisfactory level by the installation of resistance spark plugs of a type approved for the engine These plugs greatly reduce the VHF noise voltage on the ignition wires, and consequently the VHF noise radiations However, some ignition noise may be heard in the phones or speaker

Shielded Ignition Systems

Many modern airplanes are now factory equipped with shielded ignition systems Shielding kits and accessories are available for installation on other aircraft

Shielded ignition systems have the advantage over resistance spark plugs of giving more complete VHF noise suppression However, they are more expensive and difficult to install Shielding the ignition system encases in metal all parts of the circuits which might radiate VHF noise Special spark plugs must be installed, and ignition wire having a metallic-braid covering and special end connectors must be used between the spark plugs and magneto A shielded metal cover for the magneto is also necessary Insulating washers must not be used between mating surfaces of shield connectors and the connectors must be tight All connections should be periodically inspected to insure that they are mechanically and electrically good

Practical Application of Noise-Reducing Techniques

On aircraft equipped with shielded ignition systems

(1) Install VHF receiving equipment as recommended in instruction book supplied therewith Proper shock mounting of the receiver is highly recommended since excessive vibrations may cause erratic operation especially at greater distances from the station

(2) Install V antenna as recommended in the Antenna Location section and the figures of this pamphlet

(3) Inspect shielded ignition system to be sure that all connections are electrically and mechanically secure

On aircraft not equipped with shielded ignition systems

(1) Install VHF receiving equipment as recommended in instruction book supplied therewith Proper shock mounting of the receiver is recommended for reasons stated previously

(2) Install V antenna as recommended in the Antenna Location section and the figures of this pamphlet

(3) Replace all spark plugs with 10,000 ohm resistor plugs of a type approved for the engine

Interference other than ignition noise

In case electrical noise still exists after following the instructions, inspect the voltage regulator and generator to determine that they are in good operating condition Wires associated with the ignition system should not be paralleled and tied to other electrical wiring

Interference from electrical equipment other than the ignition system is usually much less than that produced by the ignition system itself In view of this fact, and since there are other publications which deal with these problems in great detail, no attempt to outline corrective measures has been made in this manual If interference other than ignition noise is encountered, reference may be made to Stage V of the main report or to the following publication

"Elimination of Radio Interference in Aircraft - NAVAER 16-5O-517" March 1, 1946

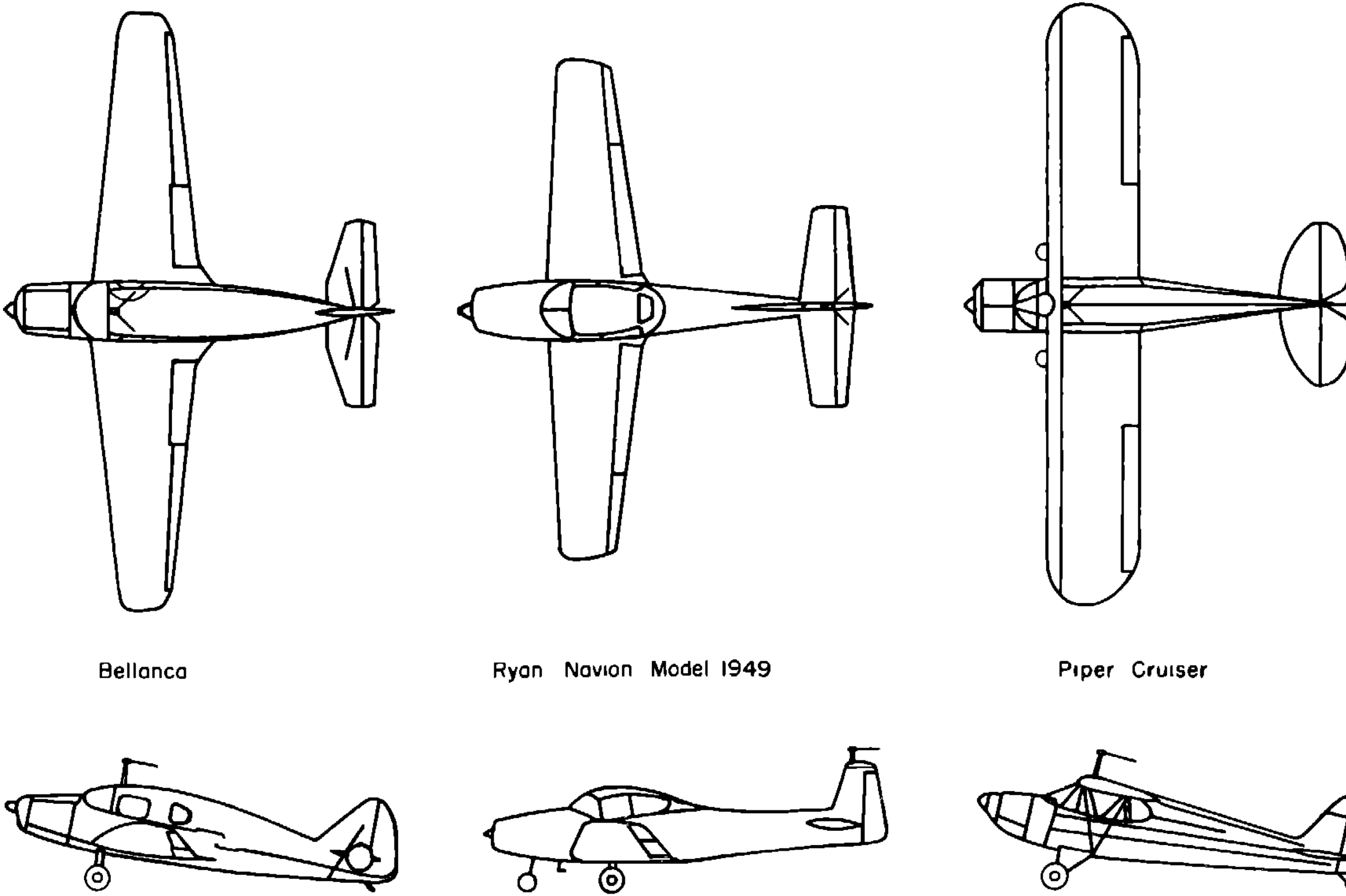


Fig 54 Location of V-109 Antenna on Aircraft

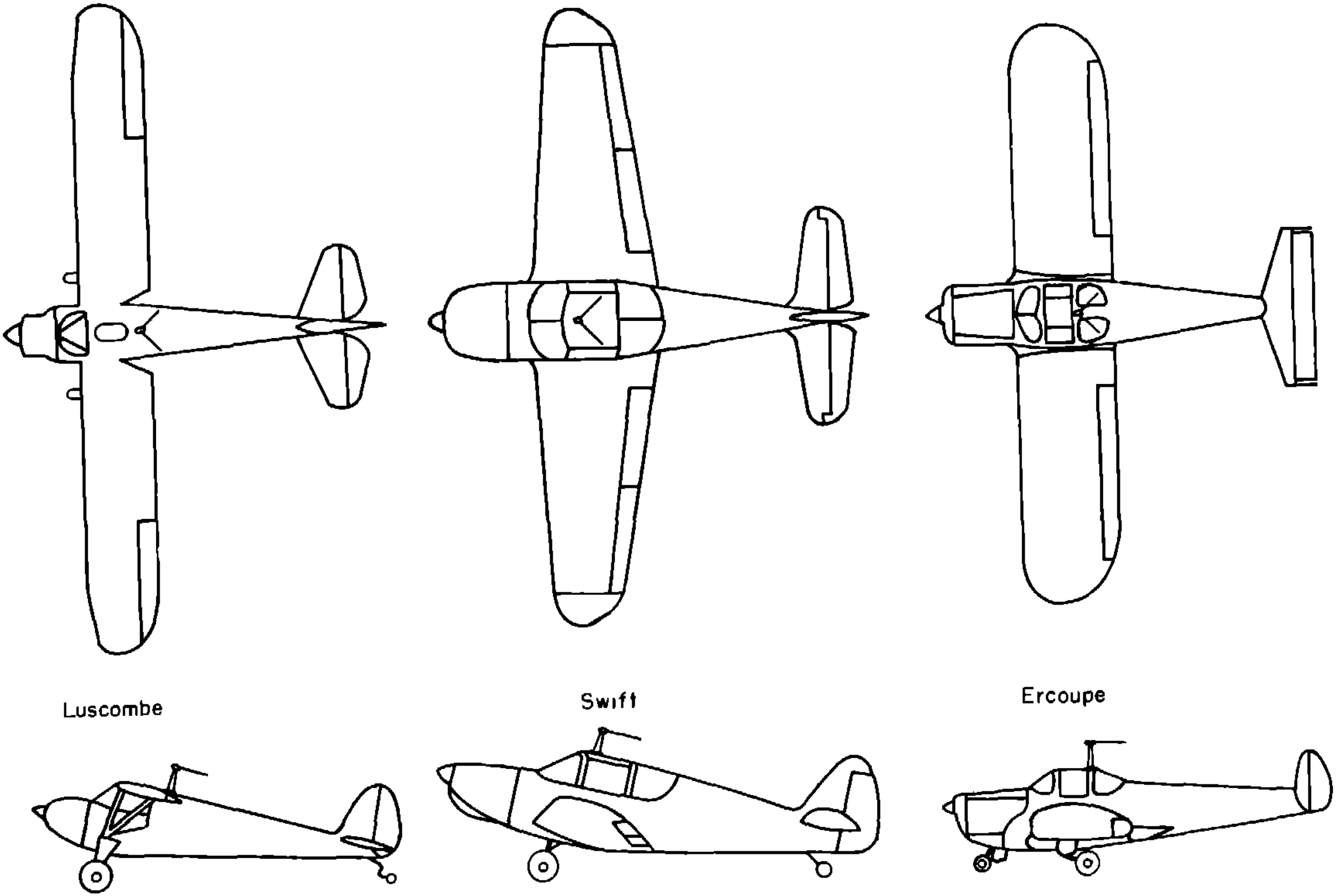


Fig 55 Location of V-109 Antenna on Aircraft

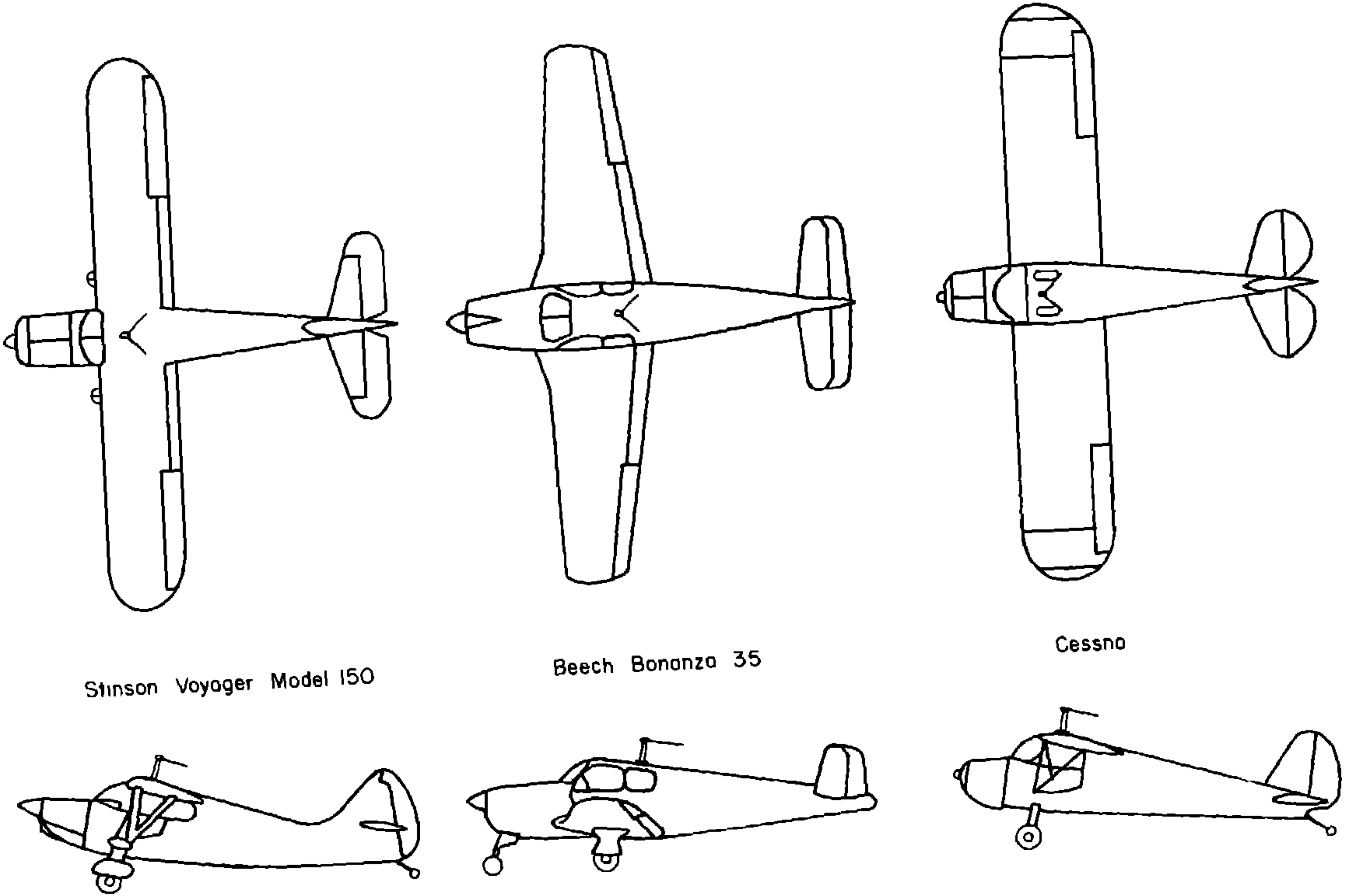


Fig 56 Location of V-109 Antenna on Aircraft

APPENDIX II

Additional Flight Tests

Due to the results obtained in Flight 10 using a NARCO antenna, it was deemed advisable to make further tests of this antenna at the Technical Development and Evaluation Center

A V-109 antenna was mounted over the hatch of a DC-3 aircraft and tests Nos 2, 3 and 5 as described under Stage II, "Flight Tests," of this report were made, using NARCO receiving equipment This antenna was then removed and a NARCO antenna mounted in the same position The same flight tests were repeated, using the same equipment and the same VOR station

For further comparison, a Cessna 140 and a Stinson Voyager having NARCO antenna and receiving equipment already installed were used in obtaining data on the flight tests mentioned previously

The results of these flights are shown in Table VIII It is concluded that with proper noise suppression and antenna location, the NARCO antenna performance will be nearly equivalent to that of the V-109

TABLE VIII

AIRCRAFT	TYPE ANTENNA AND LOCATION	SUPPRESSION USED	TEST NO 2 DOUBLE COURSE WIDTH DISTANCE MILES To	From	TEST NO 3 20 MILE COURSE WIDTH DEGREES North	East	South	West	TEST NO 5 READABILITY LIMIT MILES
DC-3	V-109 over hatch	Shielded	45 5	46	30	32	30	31	50
DC-3	NARCO over hatch	Shielded	43	44	30	29	30	29	47
Stinson Voyager	NARCO 12 inches Behind Windshield	None	37	30	38	35	32	35	40
Stinson Voyager	NARCO 12 inches Behind Windshield	Resistance Plugs 10,000 ohm	41	39	35	35	35	40	43
Cessna 140	NARCO 10 inches Behind Windshield	Shielded	43	41	32	30	30	32	47

GPO 81-102100