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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

# TRIALS OF A NEW ANTENNA AND ROTATING COUPLER FOR A.A. NO. 4, MK VI (MZPI)

BY

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OTTAWA

NOVEMBER 1950

## ABSTRACT

The present MZPI antenna and rotating coupler suffer from the disadvantages of narrow bandwidth, low power-handling capacity and instability during beam switching. A new antenna and rotating coupler have been designed and built by the Radio and Electrical Engineering Division of the National Research Council. The tests and flight trials described in this report have shown that considerable improvement has been effected.

# ILLUSTRATIONS



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# TRIALS OF A NEW ANTENNA AND ROTATING COUPLER

# FOR A.A. No.4, Mk.VI (MZPI)

## 1. Introduction

The present MZPI antenna and rotating coupler suffer from the following disadvantages: the bandwidth is so narrow that magnetrons must be selected; the power-handling capacity is too low for developments which are contemplated in the near future, and the automatic frequency control is unstable due to mismatch which occurs during beam switching. A new antenna has been designed and built by the Radio and Electrical Engineering Division of the National Research Council to remove these limitations. A series of tests and flight trials has been carried out to determine the effectiveness of the new antenna.

## 2. Brief Description of the Old MZPI Antenna

Fig.1 is a photograph of the old MZPI antenna. It is made up of 13-foot wave guide arrays, each with 50 resonant slots cut longitudinally in the broad face of the wave guide, spaced $\frac{\lambda_G}{2}$ apart, and illuminated with a 4-to-1 power taper. These arrays are stacked vertically in two groups — one group of three forming the short-range array, and the other group of six forming the long-range array. Radio-frequency power is directed to the short-range array, or to the top or the bottom of the long-range array, by resonant ring switches in the feed system. Each of these three conditions produces a beam at a different angle above the horizon. Thus there are three beams, centered at 6.75°, 13.25° and 32° above the horizon. By a mechanical adjustment to the array the three beams can be raised or lowered together 3° from these positions. The above values, however, are regarded as the normal operating positions.

The horizontal beam width to the half-field-strength points of the old antenna is 2°, and the vertical beam widths are:

| | |
|---|---|
| Low | 14° |
| Medium | 17° |
| High | 36° |

The theoretical coverage of the old antenna is shown in Fig. 2.

## 3. Brief Description of the New MZPI Antenna

Photographs of the new MZPI antenna are shown in Figs.3A and 3B. It is a 13-foot waveguide array of 45 non-resonant slots, spaced more than $\frac{\lambda G}{2}$ , illuminated with a 3-to-1 power taper, feeding a 13-foot by 2.5-foot semi-parabolic cylinder through a flared horn. Three beams, centered on 6°, 15° and 30°, are produced by mechanical positioning of the reflector.

The horizontal beam width to the half-field-strength points of this antenna is 2°, and the vertical beam widths are:

| | |
|---|---|
| Low | 13.5° |
| Medium | 15.6° |
| High | 17° |

The theoretical coverage of the new antenna is shown in Fig.4.

## 4. Comparison of Beam-switching on Old and New Antennas

Only the electrical features of the beam-switching process are considered in this report. Canadian Arsenals, Limited, have reported the following voltage standing wave ratios on production models of the old MZPI antenna and distribution switch assembly:

| Wavelength (cm.) | Average V.S.W.R. | | |
|---|---|---|---|
| | High Beam | Medium Beam | Low Beam |
| 10.650 | 1.72 | 1.66 | 1.55 |
| 10.700 | 1.32 | 1.21 | 1.27 |
| 10.750 | 1.32 | 1.36 | 1.36 |

These are the voltage standing wave ratios when the switches are in the positions to produce each of the three beams. There are no data on voltage standing wave ratios during the switching operation, but it is probable that they will be much higher. It is believed that the changes in impedance during beam switching are sufficient to cause instability in the automatic frequency control.

The curve of voltage standing wave ratio against beam elevation for the new antenna is shown in Fig.5. This curve shows the voltage standing wave ratio for all elevations of the beam, and so covers the beam-switching process. It is seen that beam switching on the new antenna does not cause a significant change in impedance.

The stability of the automatic frequency control was amply borne out by the flight trials. The position of the beam was changed frequently during these operations with no evidence of instability.

It should be remembered when comparing the voltage standing wave ratios for the new and old antenna that those quoted for the old antenna are for the antenna and distribution switch assembly, whereas the curve for the new antenna includes the rotating coupler.

5. Comparison of Bandwidth of Old and New Antennas

The bandwidth of the old MZPI antenna is $\lambda$ = 10.65 to 10.75 centimeters(1).

A curve of voltage standing wave ratios against $\lambda$ for the new antenna and coupler is shown in Fig.6. The bandwidth of the new rotating coupler (10.58 to 10.94 centimeters) is narrower than that of the antenna, and therefore it determines the over-all bandwidth. The effects of wavelength changes on the pattern do not have to be considered since they are unimportant within the bandwidth of the coupler(2)(3). From Fig.6 it can be seen that for $\lambda$ = 10.58 to 10.90 centimeters, the voltage standing wave ratio of the new antenna and coupler is less than 1.26. Past experience with radars has led to the acceptance of 1.3 as a satisfactory maximum for voltage standing wave ratio. The new antenna and coupler are within this limit.

It is noted that the band of the new coupler is not centered on the wavelength 10.7 centimeters. This is due to mechanical limitations encountered in fitting the new coupler to the MZPI trailer. In order to center the band of the new coupler on 10.7 centimeters, it would be necessary to change the distance from the center of the input wave guide to the center of the output wave guide from the present value of 29.406 inches to 29.535 inches.

6. Comparison of Coverage of Old and New Antennas

Figs. 2 and 4 are the theoretical coverages of the old and new antennas. There is little difference in the low and medium beams. The high beam of the new antenna is narrower, but this does not affect the coverage seriously.

The theoretical coverage of the old MZPI antenna has already been confirmed(1). In conjunction with the Directorate of Armament Development, flight trials were undertaken to check the coverage of the new antenna. A site at the Metcalfe Road Field Station of the National Research Council was chosen. This site is flat, and therefore produces very little ground clutter. The angle of elevation to the tops of the trees is about 3°, except to the south where it is 1.5°. The pilot of the aircraft was instructed to fly over the site on a course of 180° and the aircraft was tracked on the radar. The signal received for each revolution of the antenna was recorded as "strong", "weak" or "no signal". When radar contact was lost the pilot of the aircraft was instructed to return towards the radar on course 0°, and the received signal was recorded in the same way. Runs were made at altitudes of 3, 5, 10, 15 and 20 thousand feet, for high, medium and low beam, with a "Dakota" aircraft.

The data from these flights are plotted in Figs. 7, 8 and 9. The actual coverage agrees well with the theoretical for altitudes up to 20,000 feet. It can be seen at once that the low beam is confirmed. Since the lower parts of the high and medium beams are confirmed, it is reasonable to assume that the upper part will be as predicted. As further evidence of this, the data from preliminary flight trials on the high and medium beams, with a "Mustang" aircraft flying up to 35,000 feet, have been included (Figs.10 and 11). From these data it can be seen that the theoretical coverage gives an accurate indication of the coverage which will be achieved in practice.

7. Comparison of Range

The only available information on the old antenna is a maximum range of 77,000 yards on "Hudson" aircraft(1) at 20,000 feet on the low beam. Maximum range on a "Dakota" at 20,000 feet on the low beam in this trial is 100,000 yards. In several subsequent flights maximum ranges of 105,000 to 110,000 yards have been obtained. Also, on preliminary trials maximum ranges of 65,000 to 70,000 yards were obtained on "Mustang" aircraft at 20,000 feet.

The new antenna cannot be expected to give greater range than the old one. The horizontal and vertical patterns of the low and medium beams are very similar and so the gains of the two antennas are approximately the same. The available data indicate that the ranges obtained are at least as great with the new antenna as with the old. An apparent increase could only be caused by one of the many random factors inherent in radar flight trials. These factors include such things as variation in aspect of the target aircraft, differences in crystals, differences in radar tuning, and differences in the weather.

During the trials on the low beam, the "Dakota" aircraft was seen at greater distance when receding than when approaching (see Fig.7). This was not expected, as propeller-driven aircraft usually give a better return when approaching, as was confirmed in later flight trials. The reason for the discrepancy in this series of flights was probably the strong cross-wind which was blowing on the day on which they were carried out. In order to maintain the proper course the pilot of the aircraft was compelled to apply a considerable correction. The aircraft, therefore, did not present a head-on view when approaching, or a tail-on view when receding. The variation of the returned power from the aircraft with change of azimuth would probably be sufficient to account for the observed results.

8. Comparison of Power-handling Capacity

The old MZPI antenna and rotating coupler are operating close to the practical limit at the present peak power of 600 kilowatts. The power-handling capacity of the new antenna and coupler has not yet been determined, because at present no source of sufficiently high power is available to test it. There is little doubt that it will be considerably greater. It is hoped that its capacity will be 2.5 megawatts.

9. Summary of Results

Comparison of old and new antenna and rotating coupler:

| | Old | New |
|---|---|---|
| Maximum Range | - - | approximately equal |
| Coverage | - - (Fig.2) | similar (Fig.4) |
| Bandwidth | 10.65 to 10.75 cm | 10.58 to 10.90 cm |
| Power-handling capacity | 600 kw | considerably greater - not yet determined |
| Beam switching | changing impedance affects A.F.C. | constant impedance does not affect A.F.C. |

## REFERENCES

(1) "Experimental MZPI Equipment", NRC Report PRA-115

(2) "The Design of High Power Slotted Arrays", D.R. Hay, NRC Report ERA-161

(3) "A High Power Rotating Coupler for MZPI", A.C. Hudson and W. Lavrench (in preparation), NRC Report ERA-191.

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FIG. 1
OLD MZPI ANTENNA

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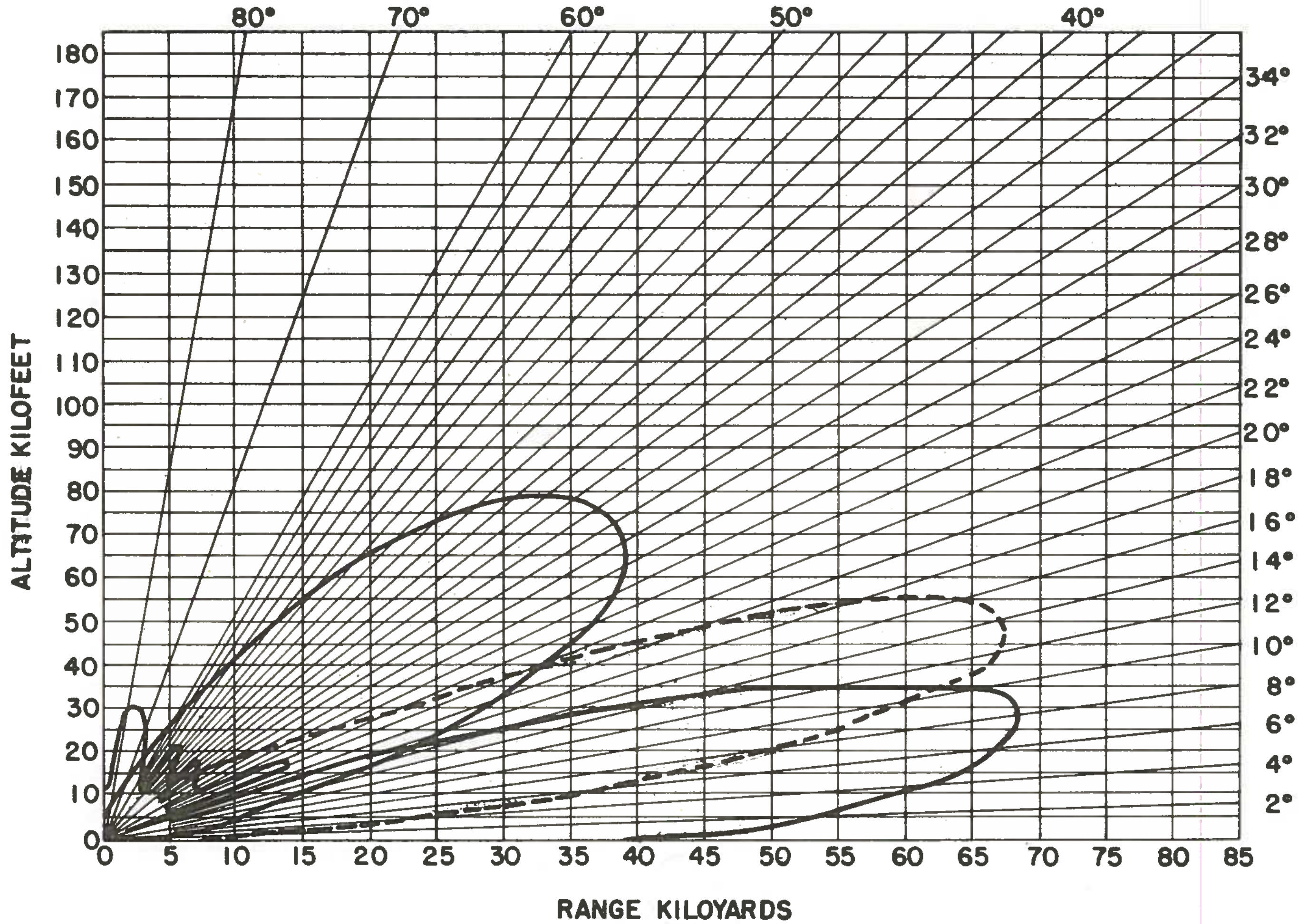
NOTE: FROM E.M.E. INSTRUCTIONS.
TELECOMMUNICATIONS 0222 (C.A.).




THEORETICAL COVERAGE OF OLD MZPI ANTENNA

FIG. 2

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Fig. 3A

New MZPI Antenna — three-quarter view from rear

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FIG. 3B
NEW MZPI ANTENNA IN TRAVELLING POSITION

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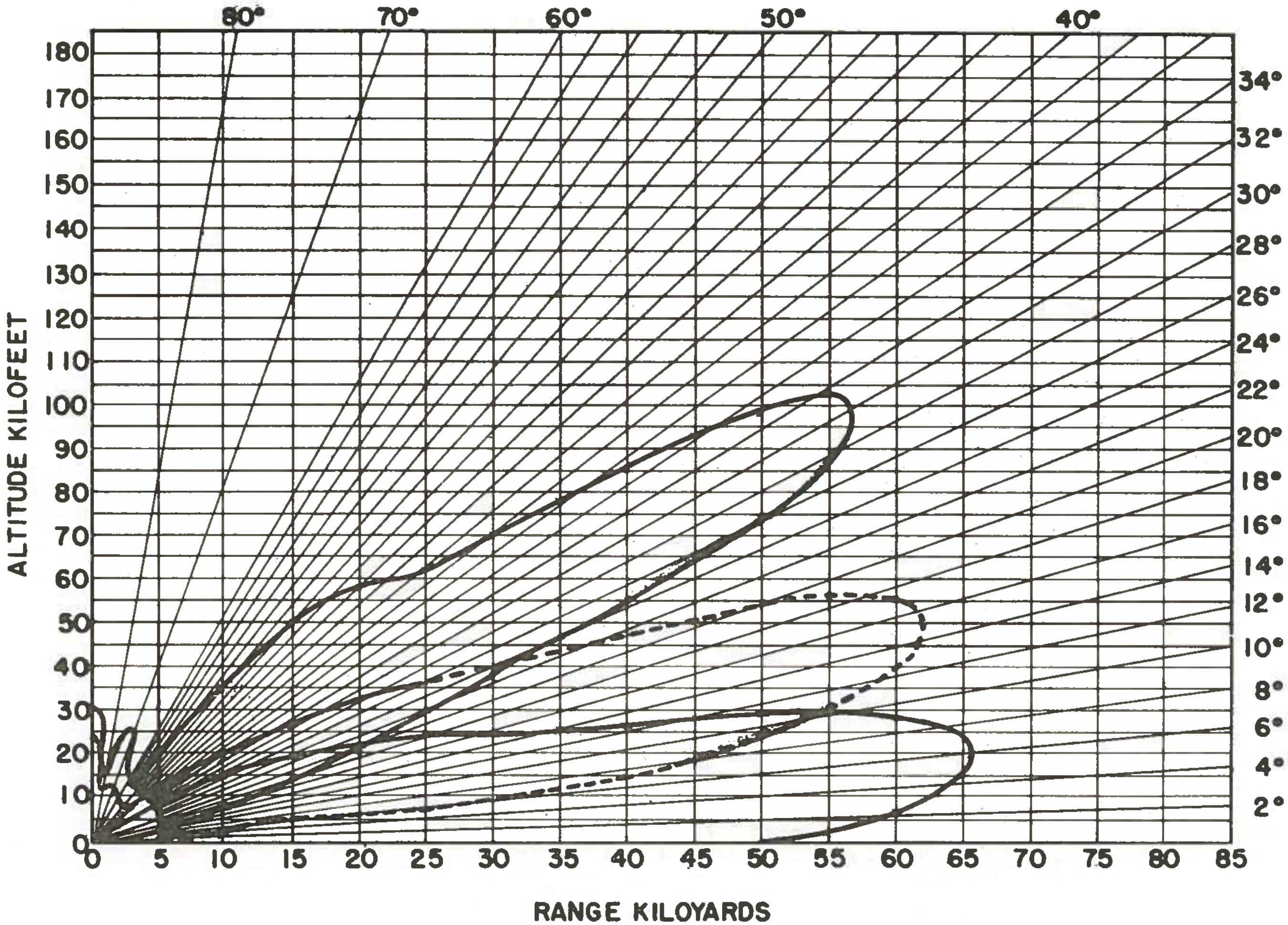


THEORETICAL COVERAGE OF NEW MZPI ANTENNA

FIG. 4

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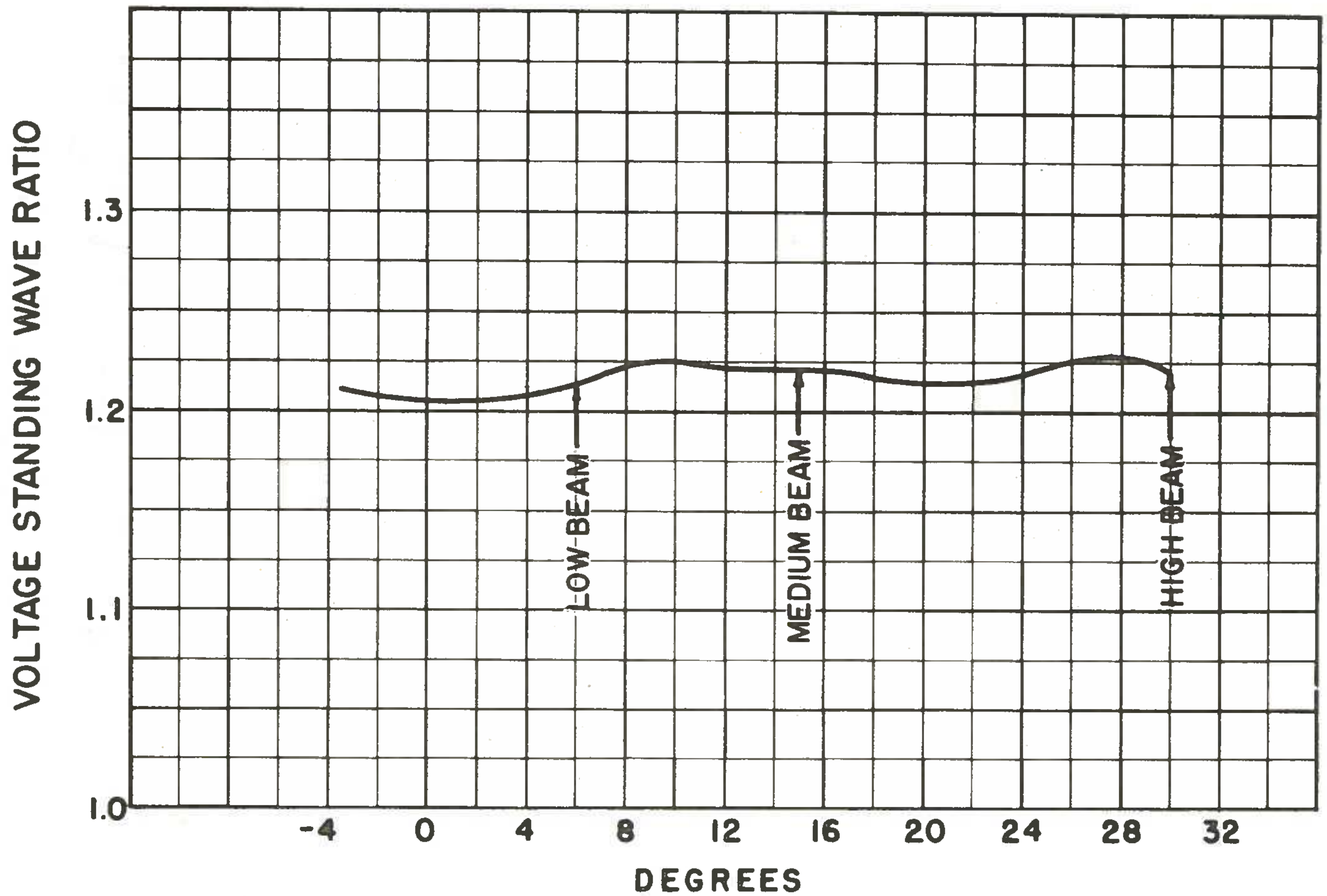


ANGLE OF ELEVATION OF CENTRE OF BEAM

( $\lambda$=10.701 CM )

VOLTAGE STANDING WAVE RATIO OF NEW ANTENNA AND ROTATING COUPLER AS ELEVATION OF BEAM IS CHANGED

FIG. 5

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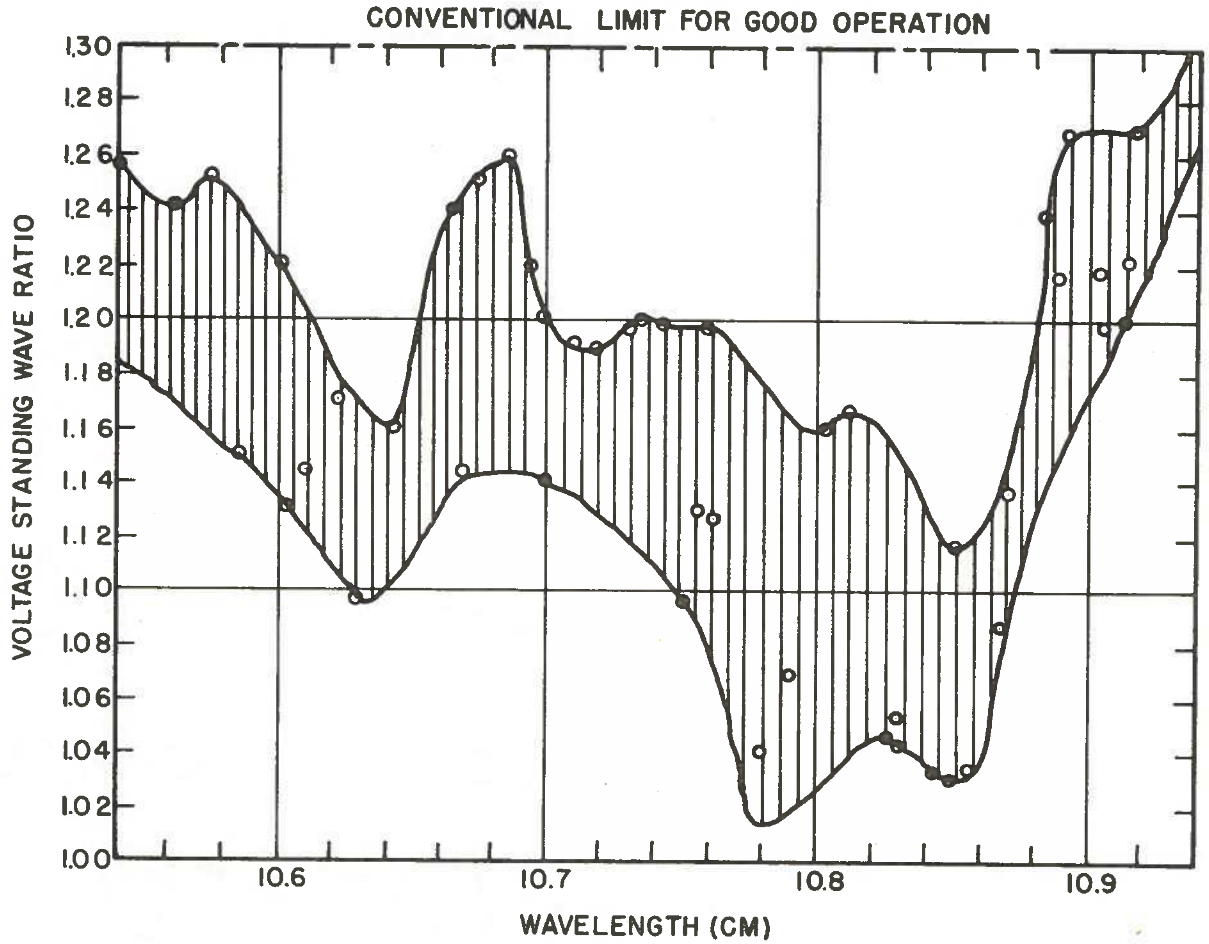


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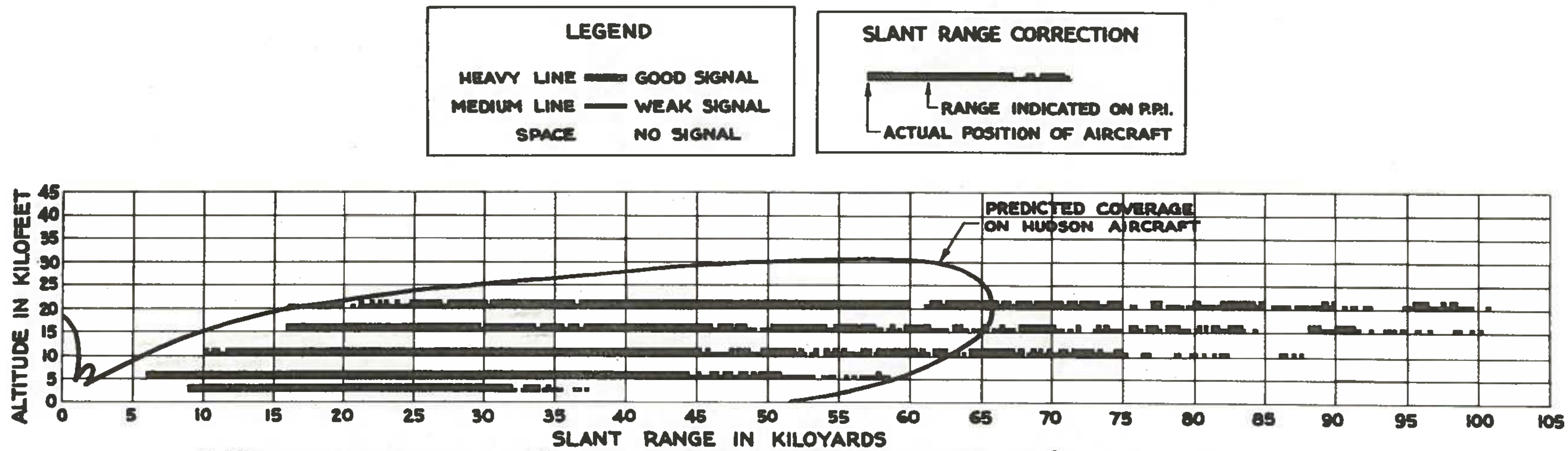
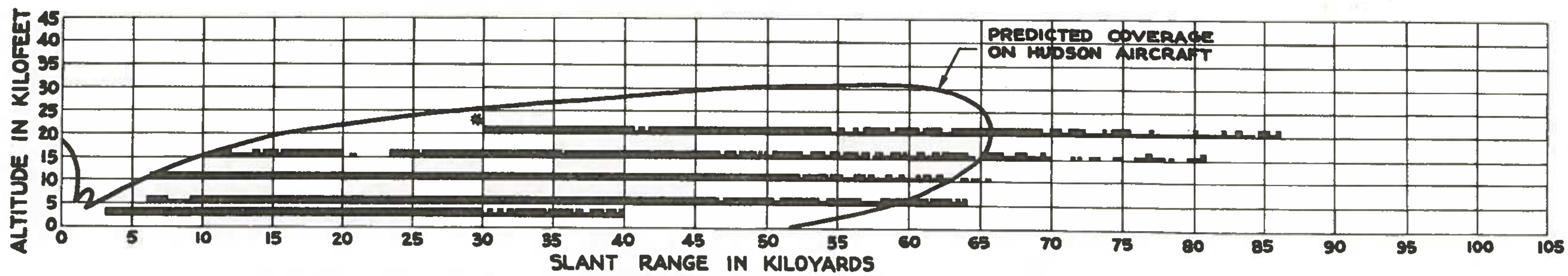
RANGE OF VALUES OF VOLTAGE STANDING WAVE RATIO
VS WAVELENGTH FOR NEW ANTENNA AND ROTATING COUPLER

FIG. 6




DAKOTA AIRCRAFT FLYING AWAY FROM RADAR–COURSE 180° – LOW BEAM




DAKOTA AIRCRAFT FLYING TOWARD RADAR–COURSE 0° – LOW BEAM

*-AIRCRAFT OFF COURSE – DID NOT APPROACH CLOSER THAN 30 KILOYARDS

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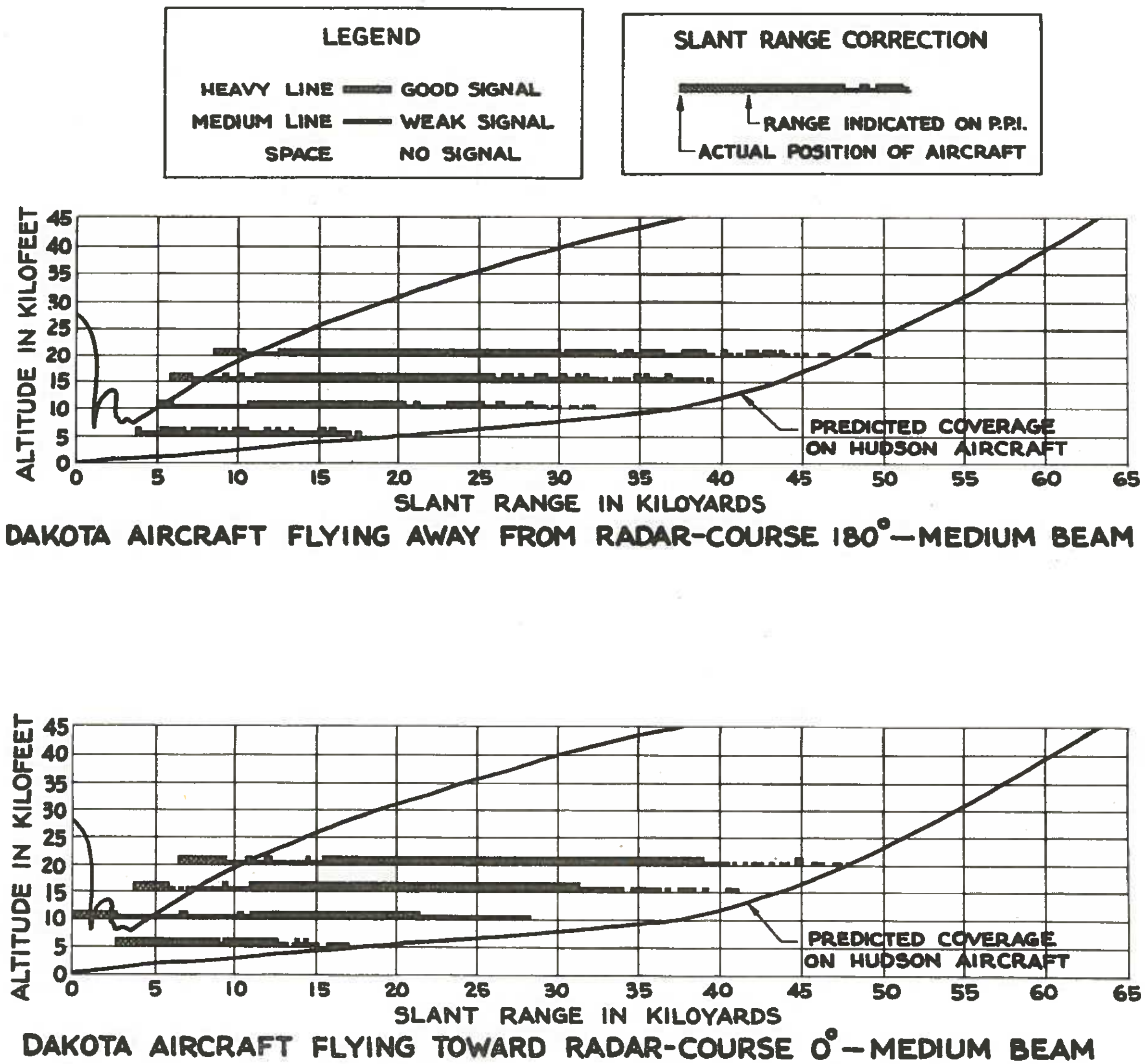
RESULTS OF TRIAL ON LOW BEAM WITH DAKOTA AIRCRAFT

FIG. 7




RESULTS OF TRIAL ON MEDIUM BEAM WITH DAKOTA AIRCRAFT
FIG. 8

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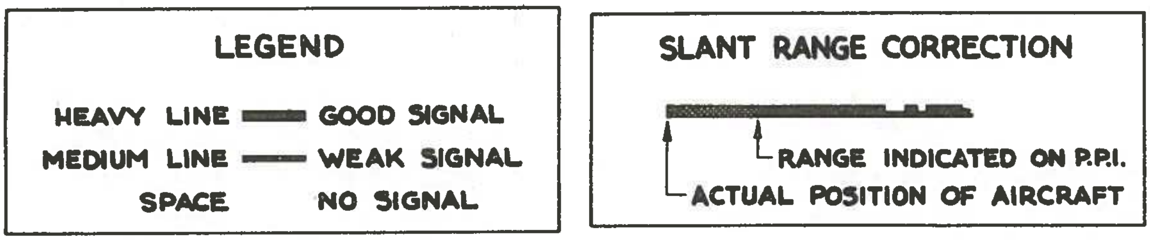
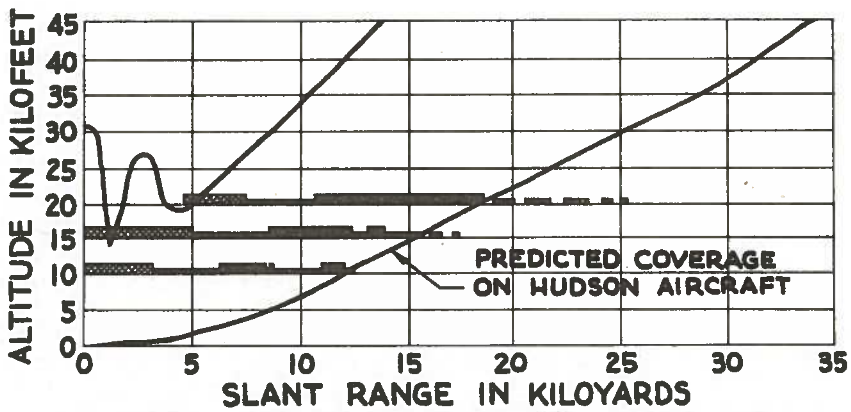
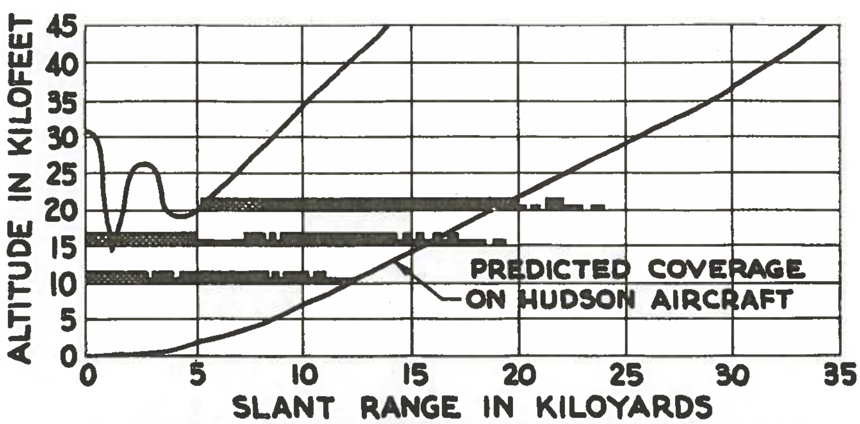



DAKOTA AIRCRAFT FLYING AWAY FROM RADAR-COURSE 180°—HIGH BEAM




DAKOTA AIRCRAFT FLYING TOWARD RADAR-COURSE 0°—HIGH BEAM

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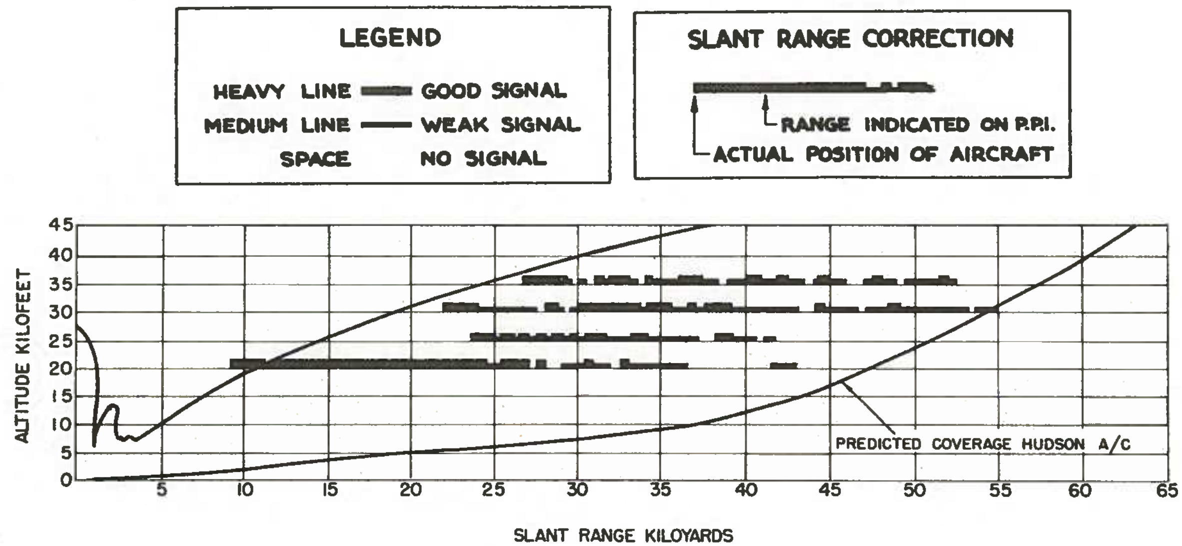
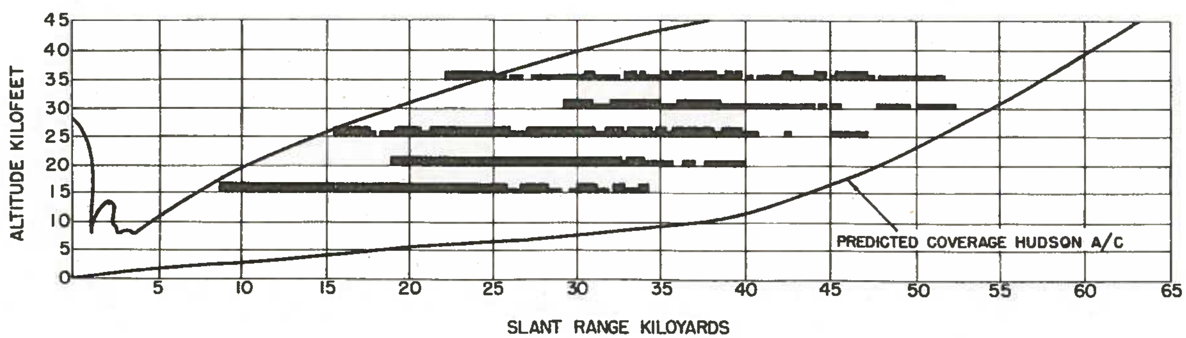
RESULTS OF TRIAL ON HIGH BEAM WITH DAKOTA AIRCRAFT

FIG. 9




MUSTANG AIRCRAFT FLYING AWAY FROM RADAR




MUSTANG AIRCRAFT FLYING TOWARD RADAR

RESULTS OF TRIAL ON MEDIUM BEAM WITH MUSTANG AIRCRAFT

FIG. 10

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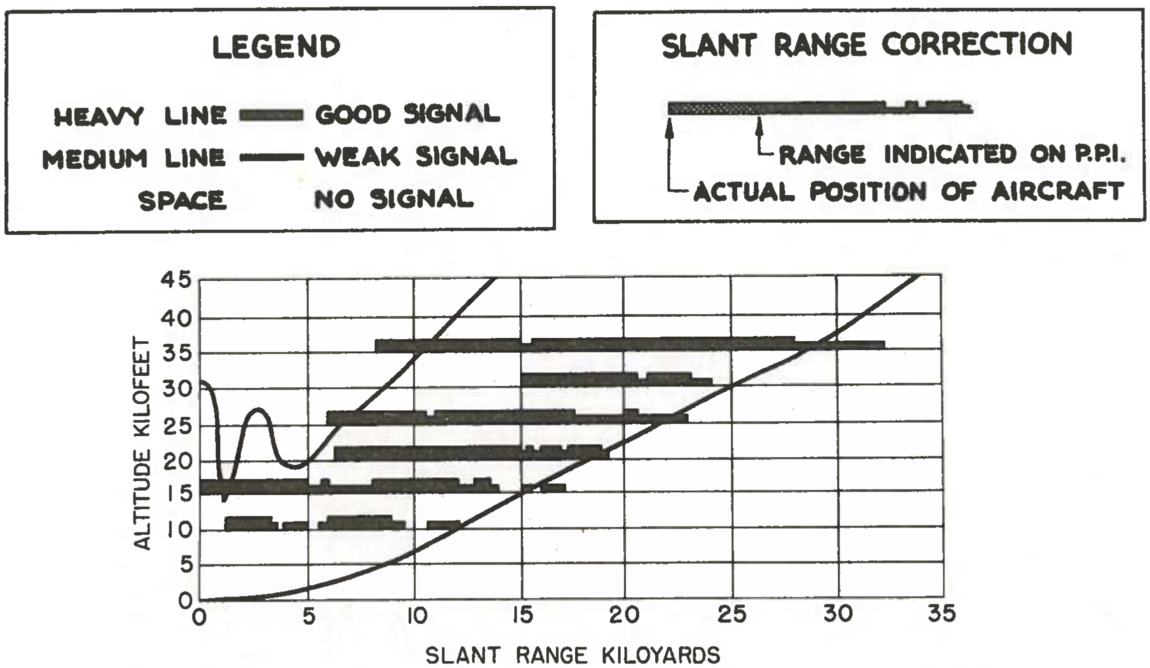


**MUSTANG AIRCRAFT FLYING AWAY FROM RADAR**


**MUSTANG AIRCRAFT FLYING TOWARD RADAR**

RESULTS OF TRIAL ON HIGH BEAM WITH MUSTANG AIRCRAFT

FIG. 11

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