DEPARTMENT OF COMMERCE

BUREAU OF AIR COMMERCE

SAFETY AND PLANNING DIVISION

REPORT NO. 8

REPORT ON

CONE OF SILENCE TESTS AT KNOXVILLE, TENNESSEE

By

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At Knoxville, Tennessee

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SUMMARY

This report covers the results of flight tests on the Knoxville, Tennessee SMRA radio range station to determine the cause of the peculiar cone of silence characteristics which had been observed at this station. Included with these results are some observations made at other range stations along the Washington-Nashville airway for purposes of comparison. This work was in the nature of a continuation of earlier ground studies carried on at Knoxville prior to commissioning, and was initiated as the result of reports from the Second Airway District patrol pilot to the effect that the Knoxville range had no cone of silence.

The tests herein described confirm this report and indicate that the difficulty is due principally to the non-reciprocal or "bent" course alignment which is required to serve the airways at this point. Probable contributory factors are the rough character of the terrain in the Knoxville area, and the close proximity of the antenna towers to railroad tracks which run immediately adjacent to the site. It is concluded that, in the selection of sites, factors such as railroad tracks, power lines, and rough terrain should be taken into consideration in order to avoid bent and multiple courses.

INTRODUCTION

The Knoxville station was the first of the new simultaneous range and broadcast stations to be installed for service operation on the

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Federal Airways. At the time of its installation it differed too from other ranges in that the tower radiators were equipped with counterpoise systems designed to minimize variations in antenna capacity and to provide improved course stability. Prior to the commissioning of this station in November of 1936, extensive ground tests were carried on to determine the effectiveness of the counterpoises, and to check experimentally the effect of course bending where a tuned center tower is involved, as is the case at all simultaneous type ranges. The results of these tests indicated that the counterpoise systems practically eliminated variations in antenna capacity. Also, no difficulty was encountered in securing the desired course alignment by conventional methods which checked with conclusions reached through theoretical considerations, that the effect of the center tower on the directional field is small.

All of the information available as a result of the original ground tests indicated that entirely normal operation with greatly improved stability could be expected from the Knoxville range. Shortly after the station was commissioned, however, the district patrol pilot reported that he could find no cone of silence over the station although in other respects it was operating satisfactorily with all courses aligned in accordance with published bearings. Since the Bureau anticipates the installation of a large number of stations similar to the one at Knoxville, it was considered desirable to investigate this condition more fully in order to determine whether or not it was brought about by the type of transmission employed or by some peculiarity of the equipment. Accordingly a flight was made to Knoxville with airplane NS-62 on July 6, 1937 to carry on this investigation.

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APPARATUS

In order to check accurately the cone of silence characteristics at Knoxville, an Esterline-Angus recording milliammeter was connected in the output of the aircraft receiver so that meter readings were proportional to the field intensity of the received signal. The moving element of this meter is sufficiently fast to follow the keying of the range and thus provide a record of the accuracy with which the course was flown as well as the rapid changes of field intensity in the vicinity of the station. As an additional check on the progress of the ship over the station, frequent reference was made to the drift indicator with which NS-62 was equipped.

FLIGHT TESTS

On the flight from Washington to Knoxville the ranges at Gordonsville, Va., Roanoke, Va., and Bristol, Tenn. were given a routine check for distance range, course alignment, and cone of silence characteristics to provide a basis of comparison for the Knoxville station. The ranges at Gordonsville and Bristol were operating with carrier transmitted from the center towers and single side band from the corner towers while Roanoke was in regular four tower operation. The cones of silence of all of these ranges were satisfactory, and no significant difference between them was noted. However, it was observed that Gordonsville and Bristol had approximately three times as great a useful distance range as Roanoke, probably because of the single side band type of transmission employed.

On the initial flight at Knoxville it was discovered that a peculiar course condition existed within a three mile radius of the station. The

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courses appeared to bend or change direction abruptly in this area so that it was very difficult to pass over the station when flying by radio alone without reference to the ground. This effect was most severe on the south leg which lies over the airport, and is parallel, for a short distance, to the L & N. railroad tracks, which pass the site within 200 feet of two of the towers. At a point about a mile from the station the tracks curve to the southeast and the course appears to follow this curvature for a short distance and then to continue on in a normal radial direction from the station. The abrupt changes in the direction of this course were unaffected by the alignment of the other courses, and are believed to be caused by the tracks, particularly in view of the fact that course bends have previously been noted under similar circumstances at other locations.

To determine the effect of course alignment and mode of operation upon the cone of silence, checks were made under the following conditions:

1. Normal simultaneous operation.
2. Normal course alignment, but with the center tower detuned and modulation applied to the corner tower transmitter as in non-simultaneous operation.
3. Simultaneous operation with reciprocal courses and 90 degree course separation.
4. Modulated operation as in 2 but course alignment as in 3.

These four conditions are representative of all of the possible operating conditions of a range of this type, and the tests were designed to show the degree of improvement which could be brought about by means under our control, i.e., changes in adjustment of the equipment.

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These tests could serve only as a negative indication of the cause of the difficulty if it were due to the terrain, counterpoises, or other conditions which could not readily be changed for purposes of experiment. However, flight tests were also carried out on the Roanoke range, which was not equipped with counterpoises, in order that their effect might be determined by comparison. The tests at Roanoke were necessarily carried out during normal operation as this range was performing satisfactorily, and was serving the airways at the time.

RESULTS AND DISCUSSION

The results of the flight tests with the automatic recorder are briefly summarized in the average curves shown in figures 1 to 6 which were plotted from the chart records.

The curves of figures 1 and 2 were plotted from data taken under the first and second sets of conditions described under Flight Tests. Comparing them it is seen that no particular improvement results from changing from simultaneous to modulated range operation. In case 2 the area in which the fade occurs is somewhat wider than in case 1, but the build up is not as abrupt nor is there any appreciable difference between the two as regards the ratio of maximum surge to minimum fade signals, both being approximately 3:1. Since the regular course alignment at Knoxville involves a departure of 20 degrees from reciprocal bearings on one pair of courses, the observed cone of silence characteristics under the above two conditions may be considered as not deviating greatly from what would normally be expected. It is well known from past experience as well as theory that course bending tends to reduce the size and change the location of the cone of silence.

The curves of figures 3 and 4 show the improvement which was brought about by establishing reciprocal bearing relations between the courses. Here again there appears to be no significant difference between the cone of silence characteristics as observed during modulated and simultaneous operation. The ratio of maximum surge to minimum fade signals is approximately 10:1 in each case which is better than a three to one improvement over the normal alignment case. It is seen that the curves of figures 3 and 4 compare favorably with those of figures 5 and 6 which were taken at Roanoke during normal operation, and are considered to be fairly representative of an average normal cone of silence characteristic.

It would appear from these results that the poor cone of silence which was originally observed at Knoxville was due entirely to the irregular course alignment. However this is not considered to be the case as even under the ideal course alignment of conditions 3 and 4 it was found to be difficult if not impossible to hit the cone of silence when flying by radio alone, because of the previously mentioned bends in the courses near the station. These bends were present under all test conditions at Knoxville and it was necessary in every case to make frequent reference to land marks on the ground in order to pass over the station. It is believed that a pilot making a routine check of this range would have difficulty in flying over the station and would attribute the difficulty to a poor cone of silence rather than to the existence of bends in the courses.

CONCLUSIONS

It is believed that while the cone of silence at the Knoxville range is a poor one yet it is what would be expected under the course alignment

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employed here. The condition is aggravated by the presence of the severe bends in the courses near the station which is considered to be more serious than the poor cone of silence itself.

Unfortunately there is little that can be done to remedy the situation at the existing site. If the course alignment were changed it would be possible to bring about an improvement in the cone of silence, but this would not rectify the more serious condition of bends in the courses. These are undoubtedly caused by the railroad tracks and the nature of the terrain in the vicinity of the station, and an improvement could only be effected by relocating the station. The use of counterpoises and the simultaneous mode of transmission is believed not to enter into this problem at all.

It is concluded that bent courses and multiple courses are caused by rough terrain, railroad tracks, power lines, and other extended metallic objects as well as by reflection from mountains, and that radio range sites should be selected with these factors firmly in mind.

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FIGURE INDEX

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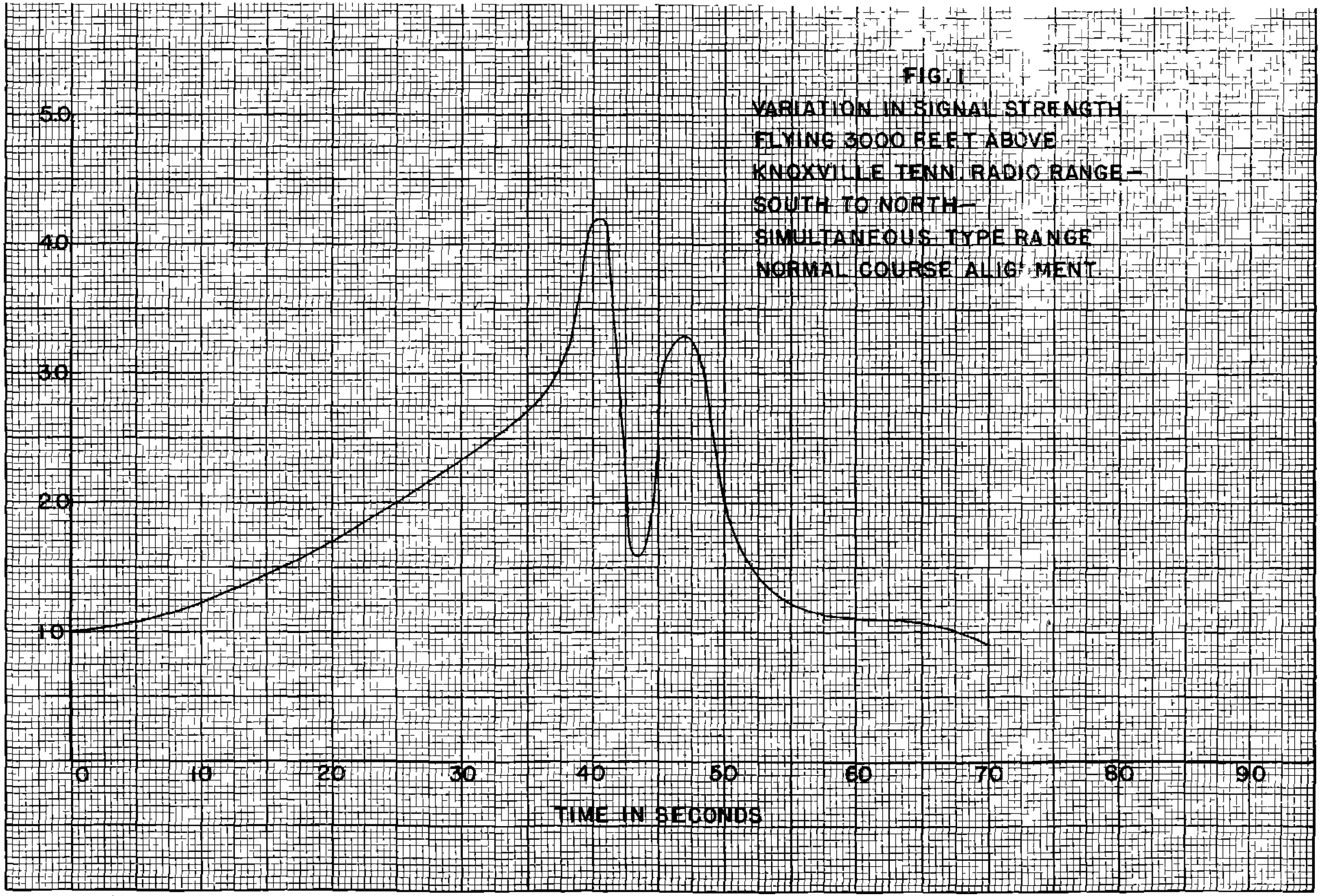
FIG. I
VARIATION IN SIGNAL STRENGTH
FLYING 3000 FEET ABOVE
KNOXVILLE TENN. RADIO RANGE –
SOUTH TO NORTH –
SIMULTANEOUS TYPE RANGE
NORMAL COURSE ALIG' MENT
5.0
4.0
3.0
2.0
1.0
0
10
20
30
40
50
60
70
80
90
TIME IN SECONDS

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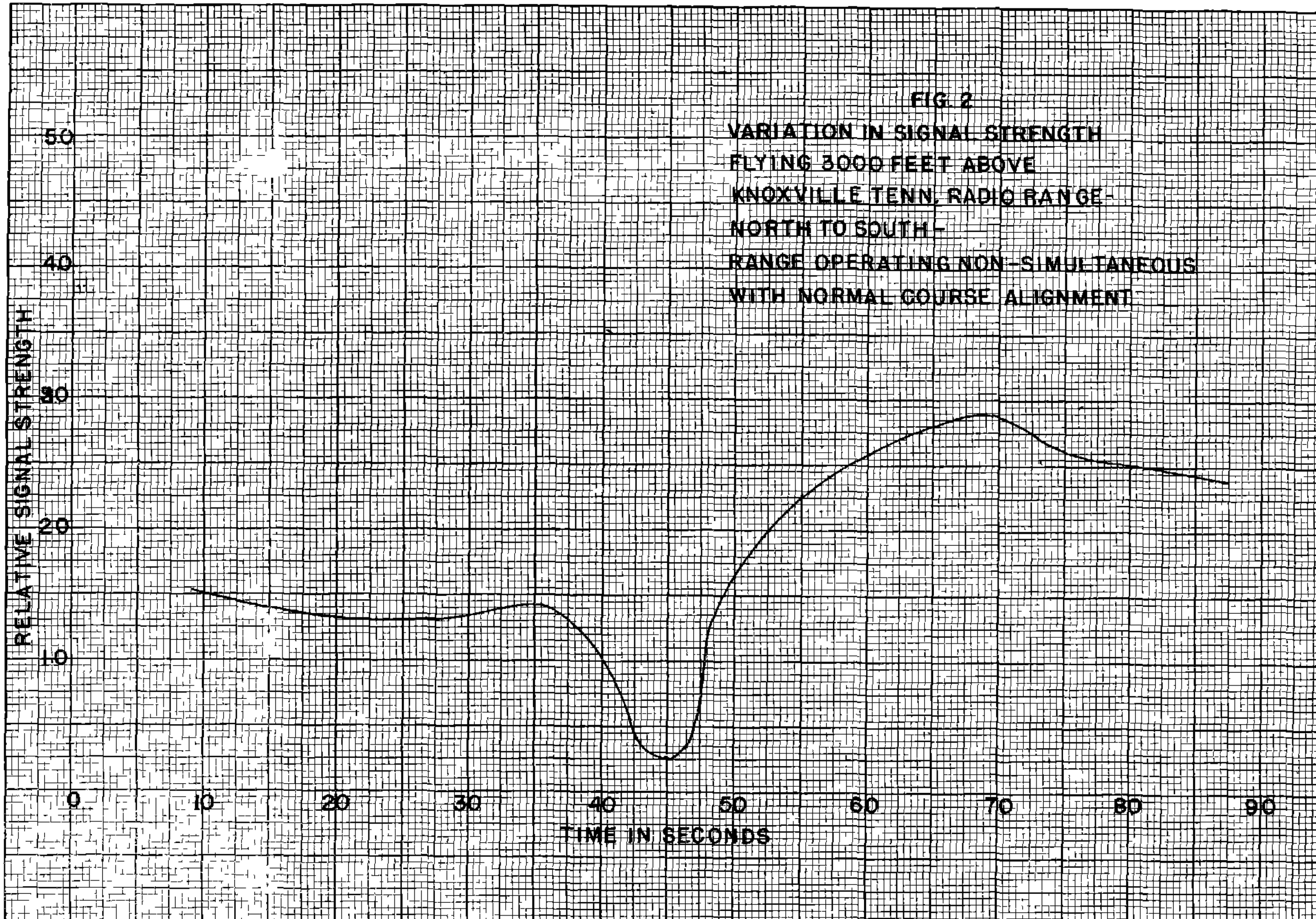

FIG. 2

VARIATION IN SIGNAL STRENGTH
FLYING 3000 FEET ABOVE
KNOXVILLE TENN. RADIO RANGE-
NORTH TO SOUTH-
RANGE OPERATING NON-SIMULTANEOUS
WITH NORMAL COURSE ALIGNMENT

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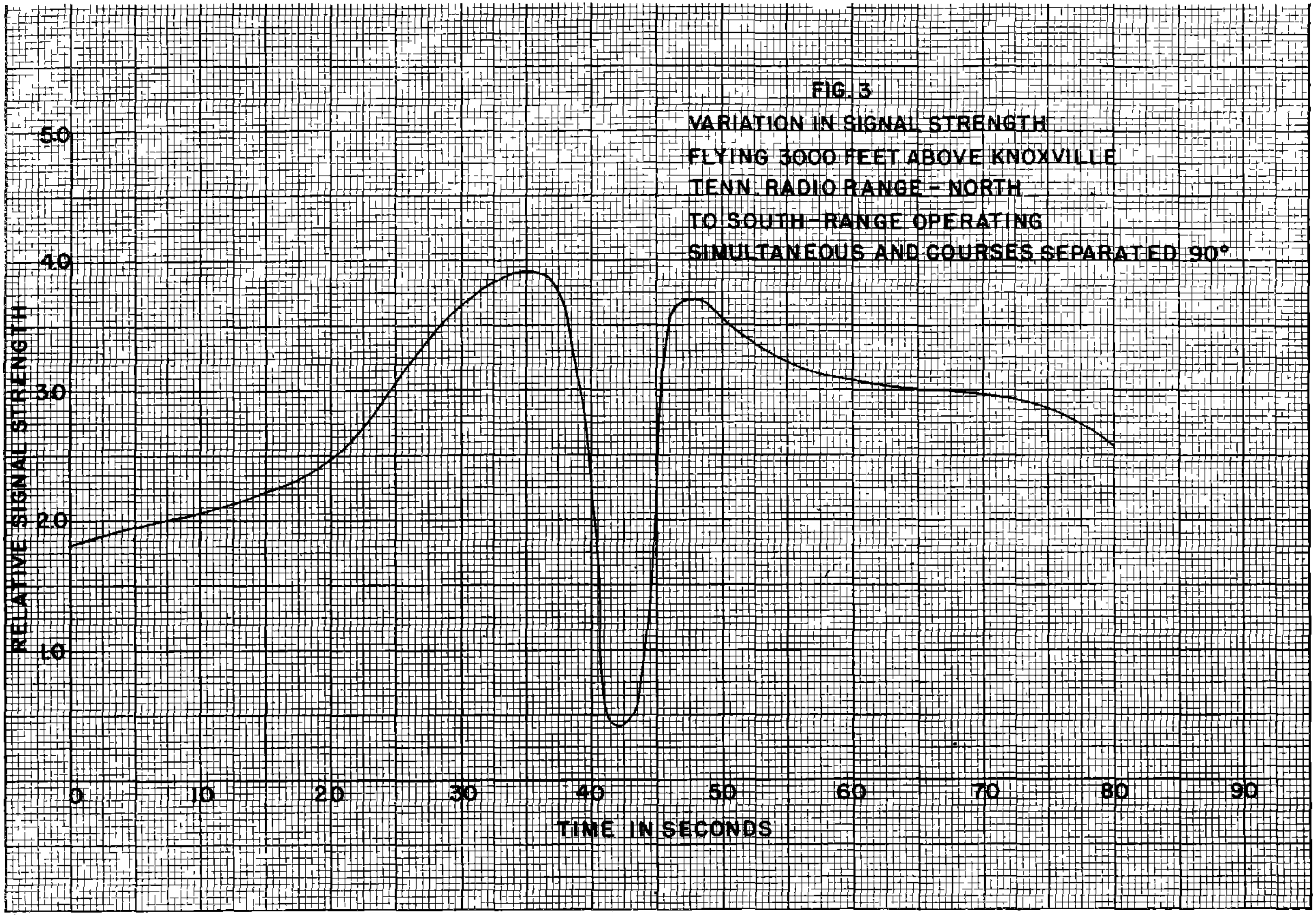
FIG. 3
VARIATION IN SIGNAL STRENGTH
FLYING 3000 FEET ABOVE KNOXVILLE
TENN. RADIO RANGE - NORTH
TO SOUTH - RANGE OPERATING
SIMULTANEOUS AND COURSES SEPARATED 90°
RELATIVE SIGNAL STRENGTH
5.0
4.0
3.0
2.0
1.0
0
10
20
30
40
50
60
70
80
90
TIME IN SECONDS

#13019

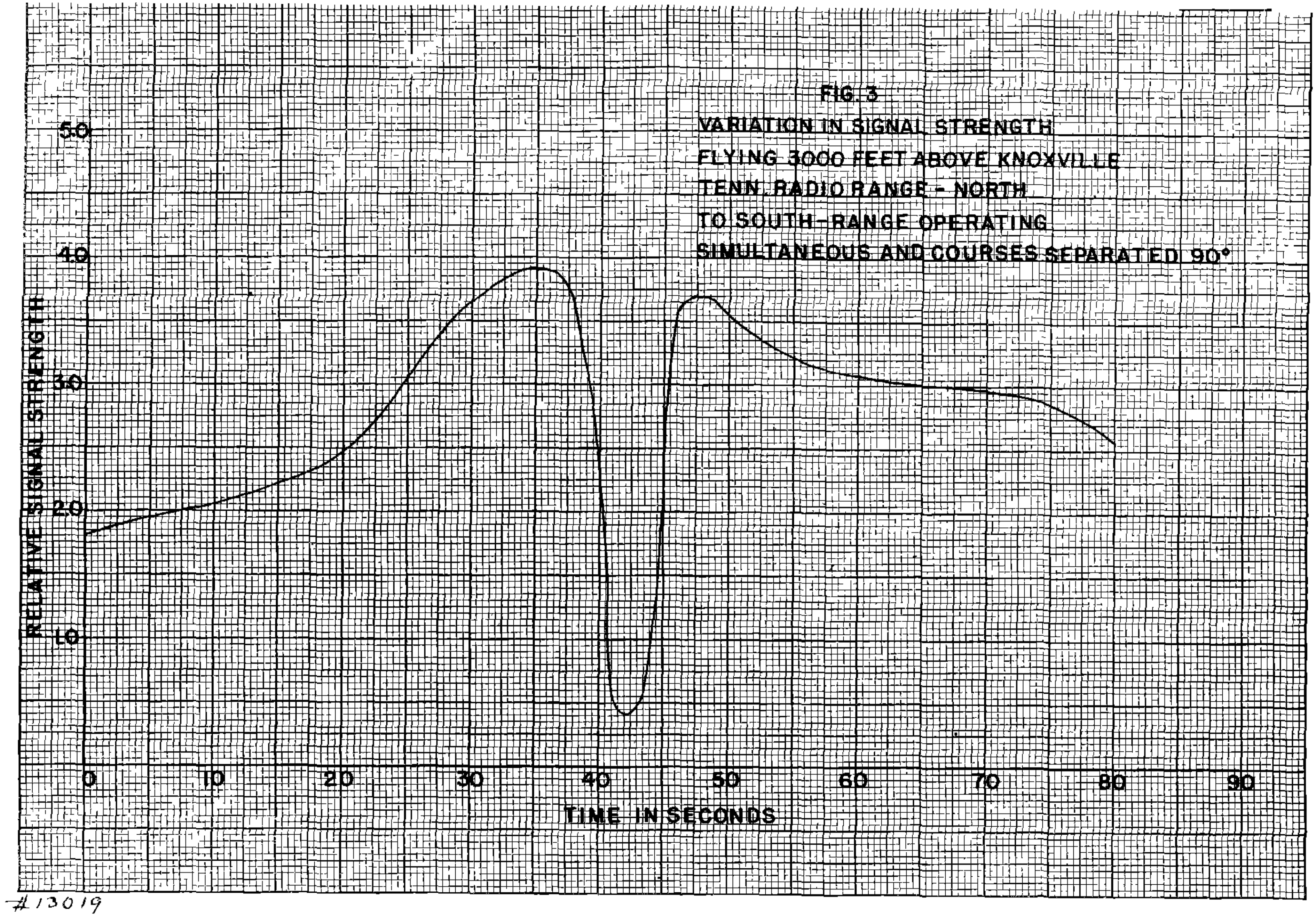
FIG. 3
VARIATION IN SIGNAL STRENGTH
FLYING 3000 FEET ABOVE KNOXVILLE
TENN. RADIO RANGE - NORTH
TO SOUTH-RANGE OPERATING
SIMULTANEOUS AND COURSES SEPARATED 90°
RELATIVE SIGNAL STRENGTH
5.0
4.0
3.0
2.0
1.0
0
10
20
30
40
50
60
70
80
90
TIME IN SECONDS
#13019

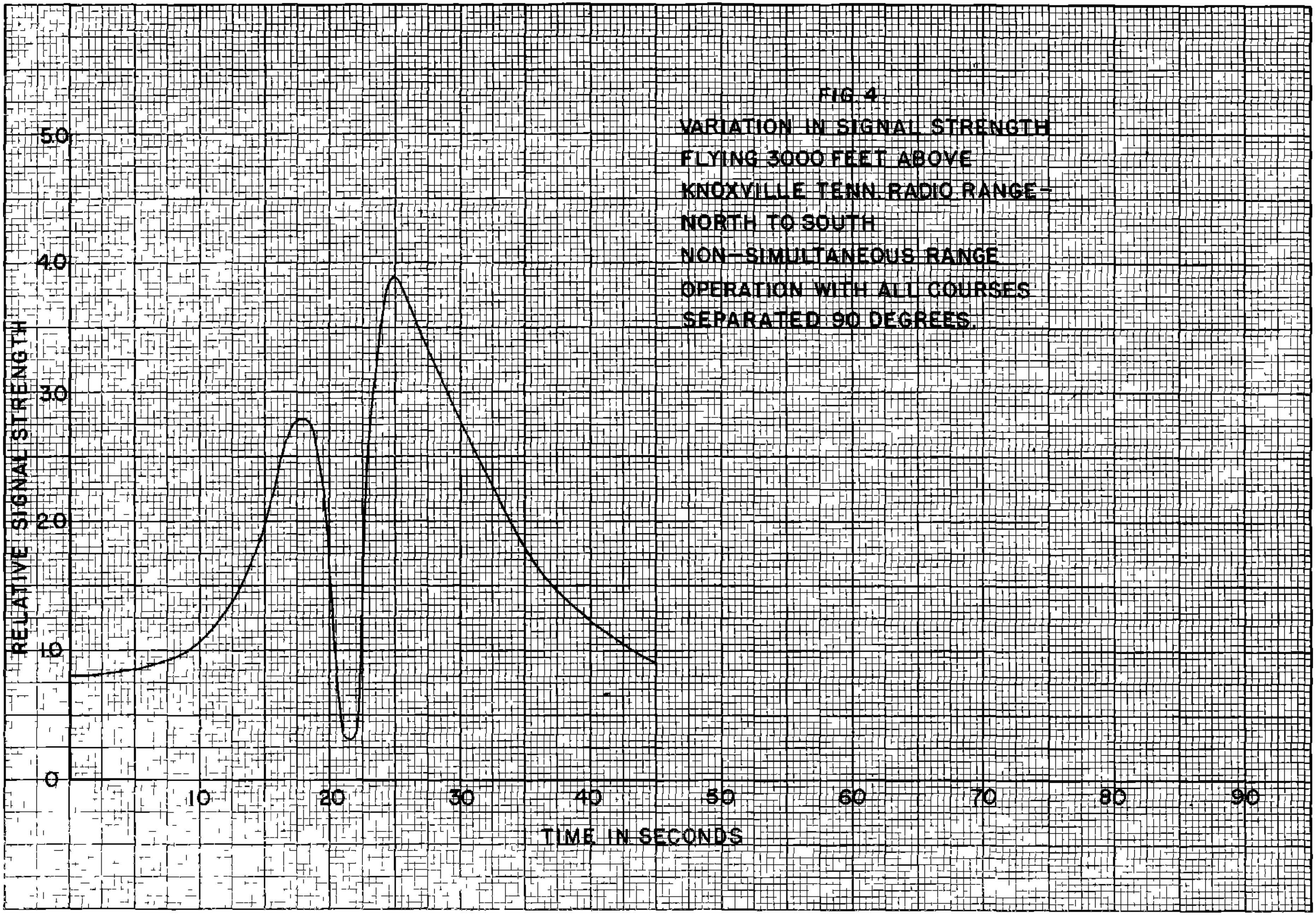

FIG. 4

VARIATION IN SIGNAL STRENGTH
FLYING 3000 FEET ABOVE
KNOXVILLE TENN. RADIO RANGE –
NORTH TO SOUTH
NON-SIMULTANEOUS RANGE
OPERATION WITH ALL COURSES
SEPARATED 90 DEGREES.

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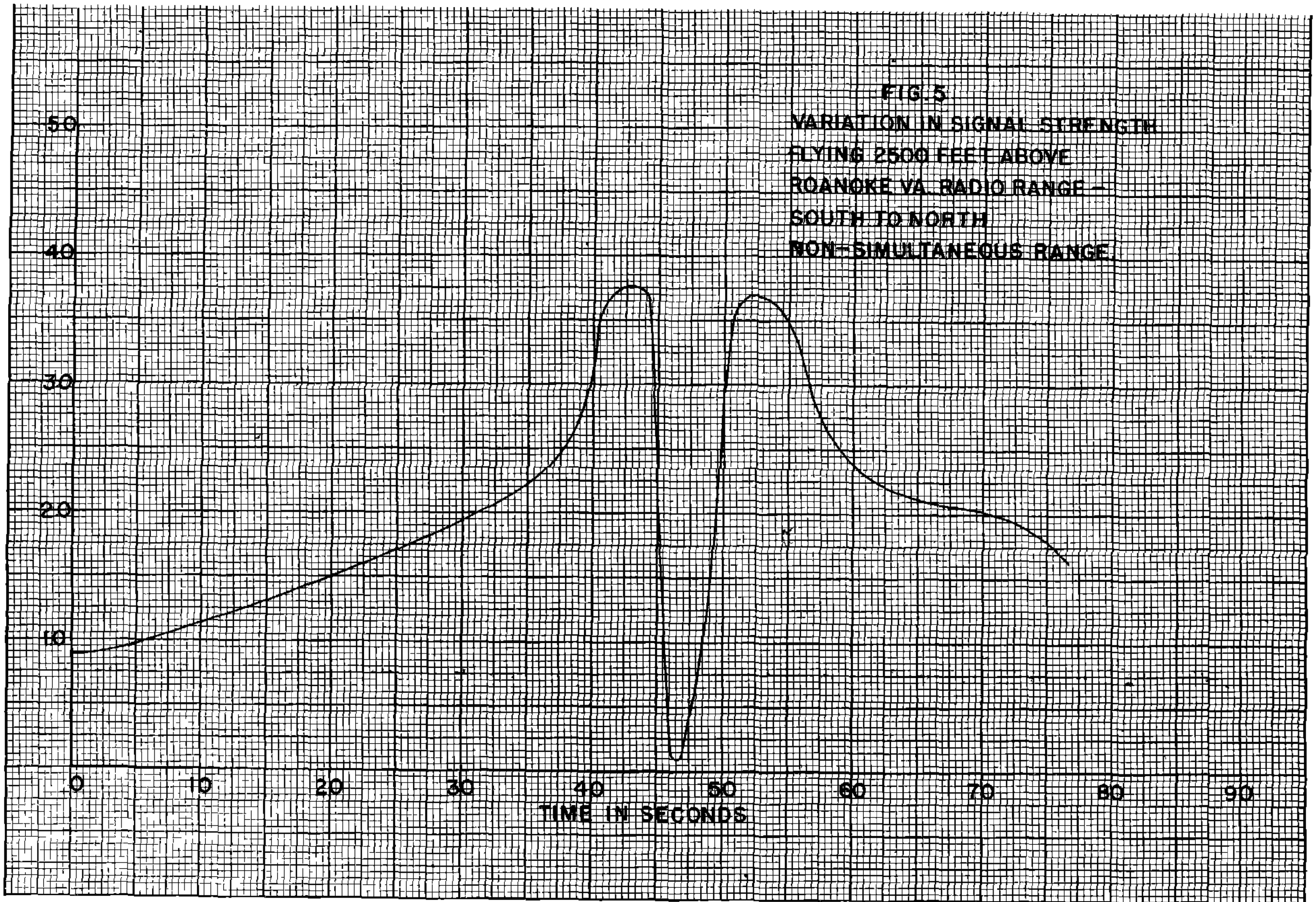

FIG. 5
VARIATION IN SIGNAL STRENGTH
FLYING 2500 FEET ABOVE
ROANOKE VA. RADIO RANGE –
SOUTH TO NORTH
NON-SIMULTANEOUS RANGE.

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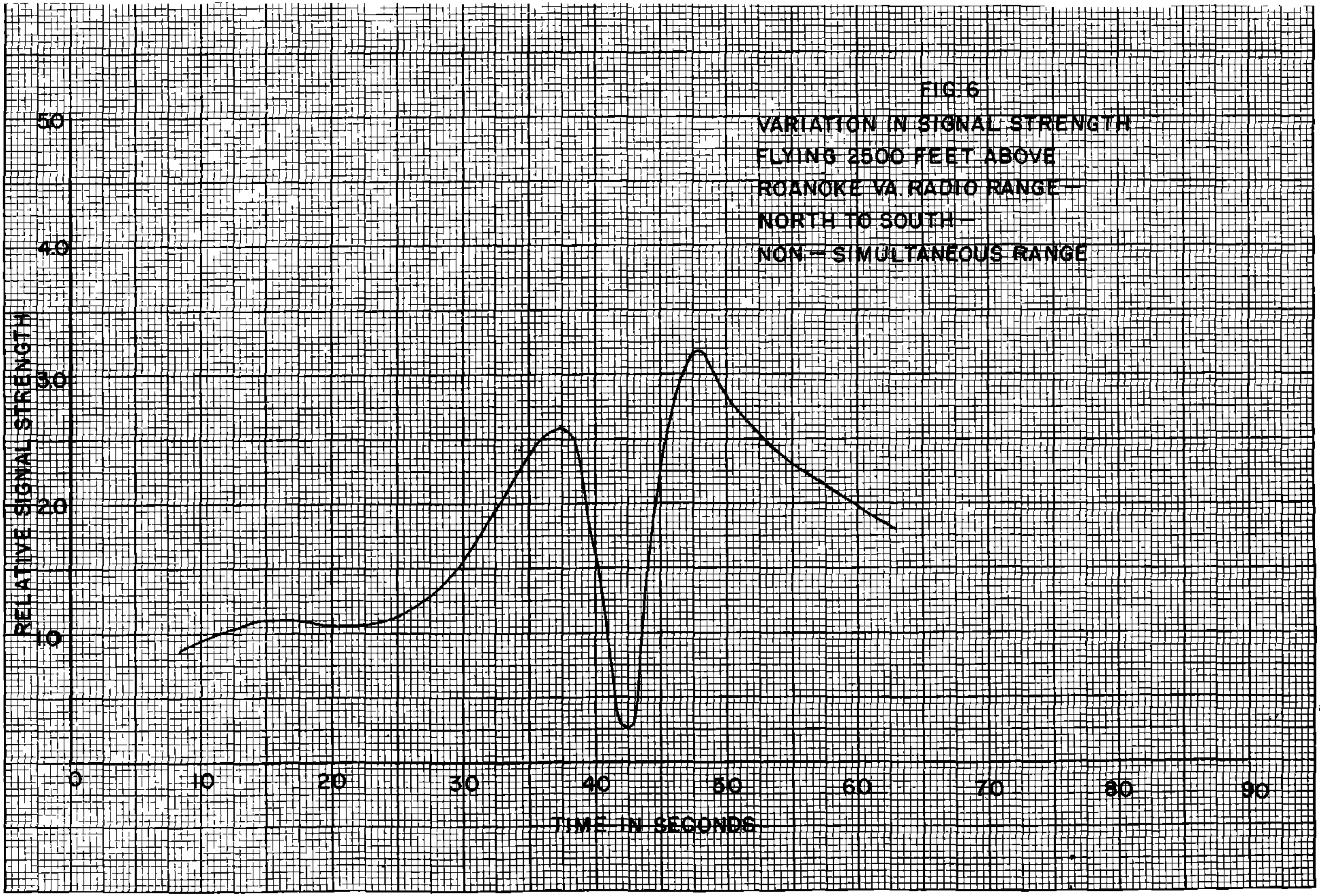

FIG. 6

VARIATION IN SIGNAL STRENGTH
FLYING 2500 FEET ABOVE
ROANOKE VA. RADIO RANGE—
NORTH TO SOUTH—
NON—SIMULTANEOUS RANGE

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