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PRELIMINARY REPORT

ON A

FOUR COURSE ULTRA HIGH FREQUENCY RADIO RANGE

by

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Radio Development Section

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SUMMARY

First experiments on an ultra high frequency radio range, having four courses, indicate that a reliable four course radio range on the ultra high frequencies is practicable, and has very desirable characteristics. Of particular significance is the utility of such a navigational aid during adverse weather conditions. Due to their freedom from high static levels and absence of the reflected sky wave, the ultra high frequencies have proven particularly well suited for short distance communications, within and somewhat beyond optical path distances. This is borne out by the successful operation of the Bureau of Air Commerce radioteletype circuit between Washington and Baltimore on frequencies within the 60-65 megacycle band, and more recently by the encouraging results obtained in experiments on 125 megacycles for airport traffic control purposes (see Report No. 2). The present state of knowledge indicates that when this development is complete it will be possible to install radio range systems at a considerably lower cost than is necessary for those now in use and that this figure may be as low as one fifth of present costs.

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INTRODUCTION

The possibility of utilizing ultra high frequencies for radio range stations soon became apparent during the course of radio experimental work. In the early part of 1937, the Radio Development Section undertook the development of such a radio range. The frequency chosen was 63 megacycles, principally because such a transmitter was already available. Numerous tests were made at the Silver Hill experimental radio station, and in June the first flight tests were made in airplane NS-62. Due to the proximity of two 125 foot steel towers and a number of antennas and transmission lines on the site, all within a radius of 75 to 500 feet of the radio range antenna, (which was only 20 feet above the ground) these flight tests indicated that severe reflections were taking place thus causing the figure-of-eight patterns to become badly scalloped, resulting in pronounced multiple range courses. Accordingly, the equipment was reinstalled at Indianapolis, where a new antenna was erected free of obstructions. The radio range was flight checked in the latter part of September.

The results obtained during these flight tests were very successful, in spite of the fact that the aircraft receiver installation on NS-78 was not entirely adequate. It is the purpose of this report to describe the equipment used, and discuss the results obtained in these first experiments.

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EQUIPMENT

The transmitter and associated equipment were installed in the inner marker station building at the Indianapolis Airport. The type TXI transmitter is crystal controlled and delivers 100 watts output at 63 megacycles to the antenna. Modulation is obtained from a standard 1020 cycle tone oscillator. A standard type AC-75 keying device was also used. The radio frequency energy was fed to the link circuit relay by means of a coaxial cable buried underground. The link circuit relay was mounted in a weather-proof metal box about five feet above the ground, and fastened to the antenna supporting pole. A type AC-74 link circuit relay was modified for operation at these frequencies, so that the armature has a greater follow-through, and contacts are about 1/4 inch in diameter. The fixed contacts are supported on isolantite insulators. These modifications were made in order to reduce the stray capacity coupling between open contacts to a minimum, and thereby produce very good "minimums" in the resultant figure-of-eight field patterns. Figure 4 is a close-up view of the link circuit relay.

The antenna system of the 63 megacycle radio range is particularly interesting in that it could be housed in a cubical space less than seven feet on a side. In figure 1 is shown a schematic of the whole antenna system. Four vertical radiators, each approximately one-half wave length long, are supported on insulators in the corners of a square about six feet on each side. Two coaxial cables,

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from the fixed contacts of the link circuit relay, feed diagonal pairs of antenna elements, such that the coaxial cables run directly to the mid-points of each antenna element. It will be noted from the figure, that diagonal pairs of elements have reversed connections to the inner and outer conductors of the cables, to provide the necessary phase reversal to produce a figure-of-eight pattern. The outside conductor of the coaxial lines and the metal housing of the link circuit relay are electrically bonded and can be grounded at any point. The whole antenna system was supported on a 25 foot pole at Indianapolis, about 60 feet from the transmitter house. A greater height would have been desirable, but would have constituted an obstruction in its present location. An obstruction light was installed in the center of the system. Figure 2 shows the entire radio range antenna system and the link circuit relay. A close-up of the antenna elements is shown in figure 3.

Since no aircraft receiver was available for flight tests, a type RUB ground station receiver was modified for 12 volt battery operation, with one concentric line radio frequency pre-selector. The receiver is a crystal controlled super-heterodyne using one stage of radio frequency amplification, and two stages of intermediate frequency amplification at 3850 kilocycles, having a band width of 60 kilocycles. Manual volume control was used throughout the tests. The antenna on NS-78 consisted of a standard low frequency vertical mast antenna extending approximately 5 feet above the fuselage.

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TESTS

Initial tests on the ultra-high frequency range installation consisted of taking field intensity measurements and determining the field strength patterns of each pair of antennas and the approximate alignment of the courses by means of ground checks. A field pattern was taken at a distance of 100 feet from the antenna (figure 5), to determine whether or not interference effects, due to reflection or diffraction of energy from surrounding objects, were present. With the exception of a few points taken in the immediate vicinity of the transmitter building, the curves were very smooth showing almost complete absence of any such effects. It was noted, too, that practically complete cancellation occurred along a line normal to the plane of an antenna pair which would indicate that the currents in the antenna elements were of the proper phase and amplitude.

The first flight checks were made across each of the courses at a distance of approximately ten miles from the station and at altitudes of from 1000 to 5000 feet. The on-course zones appeared to be about 3° wide with perfectly interlocked signals and no trace of key clicks or timbre change. No evidence of multiple courses or multiple course effect was observed, even during flights which intersected the courses at very acute angles. The cone of silence was found to be very broad and deep, the period of absolute silence ranging from 6 seconds at 1000 feet to 30 seconds at 4000 feet, while flying at 100 miles per hour.

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Later flights were made out on each of the courses to determine the distance range of the station and the effect of altitude on field intensity. It was found that the maximum usable distance of the station was approximately 50 miles, but this limitation was imposed by the high ignition noise level in the airplane rather than by rapid attenuation of the signal. It is believed that a well shielded and bonded receiver installation would largely eliminate ignition interference, and extend the usable distance of the station to about 100 miles at 10,000 feet altitude. Atmospheric static interference was not encountered during any of the tests. No multiple courses were observed during cross course flights at a distance of 50 miles from the station, and changing altitude from 2000 to 5000 feet had no apparent effect upon received field intensity. At altitudes below 2000 feet and fifty miles from the range station, the signal faded out completely.

During all flight tests it was noted that the receiving antenna on NS-78 was directive in such a way that maximum signal was received when flying away from or at an angle of 90° to the station. The reduction in received signal when flying toward the station was quite marked. While this directivity would cause variations in signal intensity when the ship was maneuvered, it never gave rise to any false course indications. It is believed that this effect could be overcome by using a short (2 foot) stub mast antenna located up near the nose of the ship.

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The alignment of the courses was checked during flight and is shown in figure 6. It was originally intended that the courses be 90° apart, but no attempt to secure such alignment was made during this preliminary work. The departure of 4° from the normal 90° relationship can be ascribed to slight inaccuracies in making the initial adjustments and no difficulty in correcting the alignment is anticipated.

RESULTS

The results obtained in the tests conducted on the ultra high frequency radio range at Indianapolis have shown that:

(1) On-course signals are of very steady character, and sound like a continuous, unkeyed tone. No timbre effect was present on any of the courses, and key clicks were entirely absent both on and off course. The adjustment of the link circuit relay was not in the least critical.

(2) No multiple courses were detected on any of the four courses. Careful checks were made, both by flying across the courses around the station at various distances, and also by flying gradually into a course and out of it.

(3) The cone-of-silence is very definite and broad, being marked by a dead silence.

(4) Although the antenna used on NS-78 showed some directional characteristics, maneuvering banks and turns never changed the character of the signal nor gave any false indications.

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(5) The antenna system for the range station is simple, rugged, and relatively inexpensive as compared to the low frequency radio range. Since the antenna system is elevated above ground and requires such small physical space and short, efficient transmission lines are used, it is anticipated that a considerably higher degree of course stability, than is possible with the low frequency range antenna system, will be obtained.

(6) Although the tests described in this report were made under fair weather conditions, previous experience on the Washington-Baltimore radioteletypewriter circuit (61 and 65 megacycles) and the 125 megacycle flight tests at Indianapolis have shown an almost complete absence of static disturbances. This is of greatest importance, and in itself is a vast improvement over the low frequency radio range, in that the range service will be practically unimpaired in bad weather when need thereof is greatest.

ECONOMIC FACTORS

The cost of the complete experimental antenna system including transmission lines was less than $250, as compared to $9400, the approximate cost of four 125 feet insulated steel towers erected and including counterpoises, transmission lines, and tuning houses. The transmitter used in these tests is valued at $2000.

Although development of the ultra high frequency radio range is not complete, and certain refinements are contemplated, it is expected that the total expenditure necessary for a radio range station with automatic standby equipment will be considerably less than that of the present low frequency range stations, probably not to exceed $6600, which is one fifth of the present range station cost.

CONCLUSIONS

It is concluded that:

(1) It is practicable to obtain a four-course radio range, the courses of which are of about the same width as that obtained on low frequencies with loop antennae, namely 3°. The courses appear somewhat broader than on the tower type range.

(2) Further tests should be carried on at Indianapolis with an improved receiver and aircraft antenna installation. A simple rod antenna about two feet in length is all that is required, and a well shielded receiver with transmission line to the antenna will materially increase the flying range.

(3) Further tests should be carried on at Silver Hill to further improve the antenna system, particularly in the coupling between the coaxial cables and antenna elements, and a further study should be made to obtain accurate control of the bearings of the courses.

(4) Tests at Indianapolis should include flights during periods of heavy atmospheric disturbances and rain static on low frequencies.

(5) Upon completion of tests at Indianapolis, the entire equipment should be reinstalled at some location in mountainous terrain, such as Pittsburgh, to determine whether or not any detrimental reflections will result in bent or multiple courses. It is believed that

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a 600 ft. x 600 ft. standard radio range plot will be sufficient to preclude any undesirable field distortions. Similar tests should also be conducted at Burbank, California, and Salt Lake City, Utah.

(6) Although the cone-of-silence is exceedingly good and unmistakable in tests to date, Z type markers should still be used.

(7) Simultaneous radio range and telephone should be investigated so that voice and range service may be provided on one high frequency channel if found practicable.

(8) The merits of the ultra high frequency radio range should be kept in mind in connection with future extensions and modernization of the Bureau of Air Commerce radio range facilities, but no definite plans for construction and installation on the airways should be made until all tests are satisfactorily completed, and actual service data are obtained on two or more such installations over at least a one year period of time.

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FIGURE INDEX

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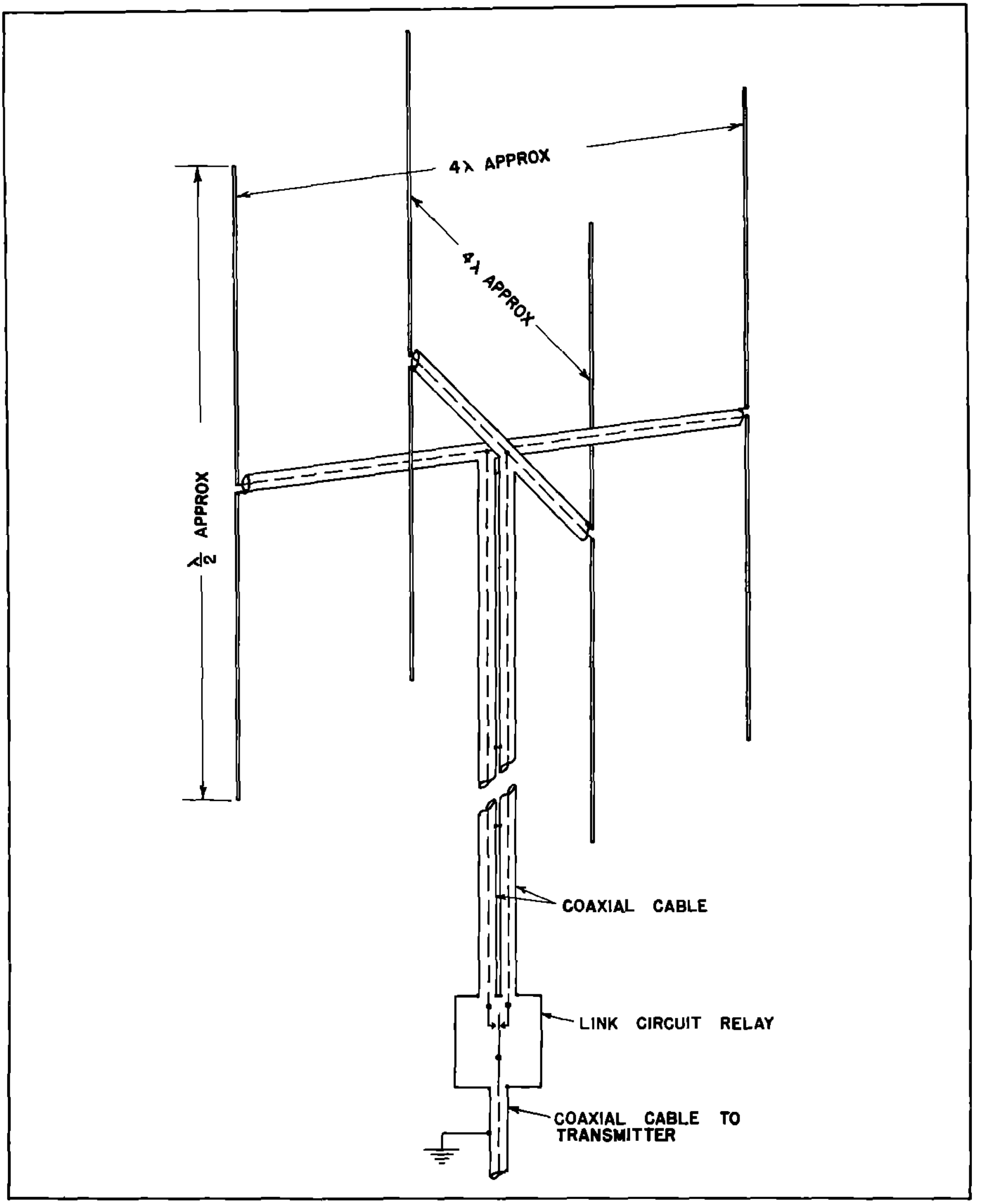

Fig.1- Schematic diagram of the UHF radio range antenna system.

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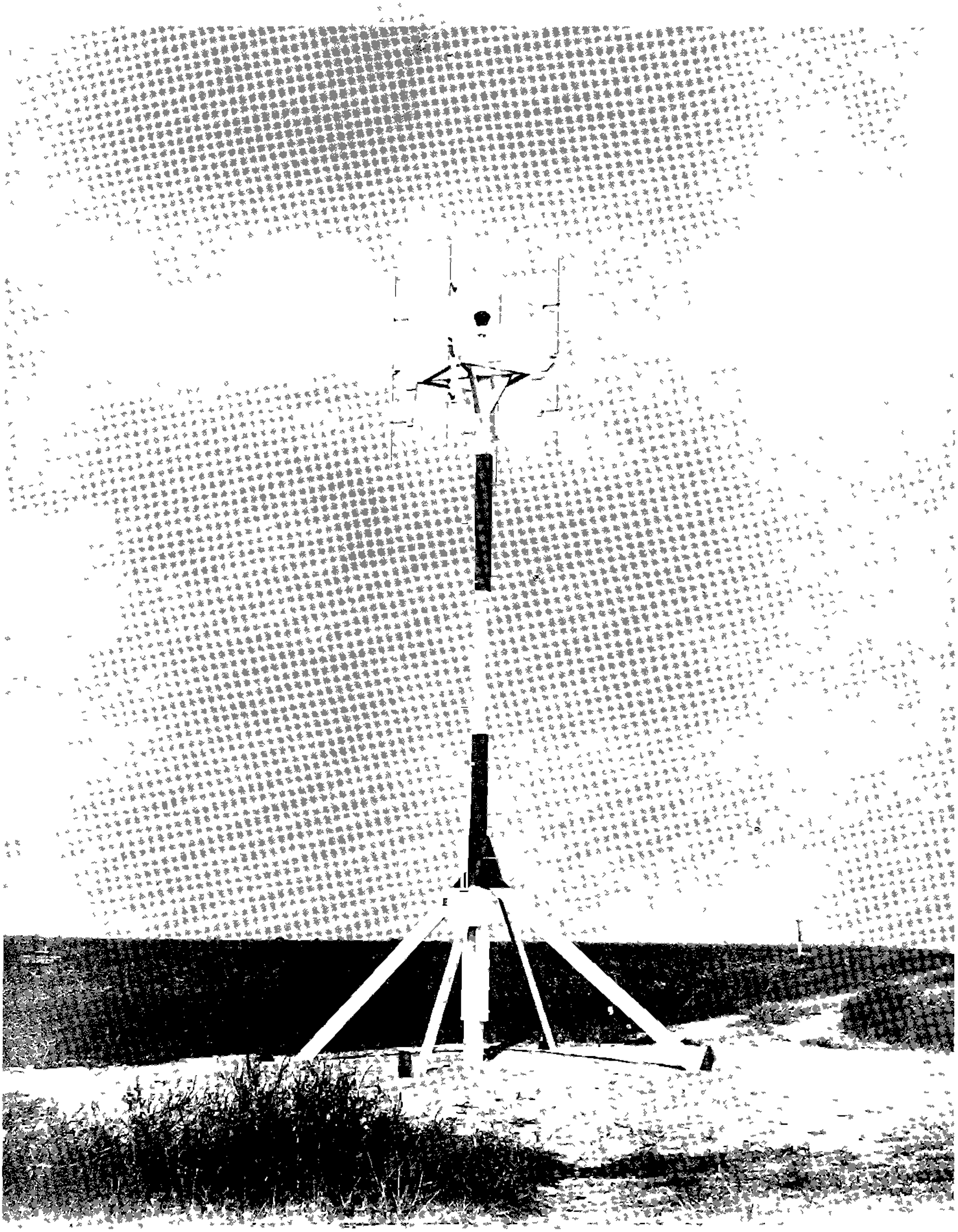

Fig. 2- The experimental radio range at Indianapolis Airport.

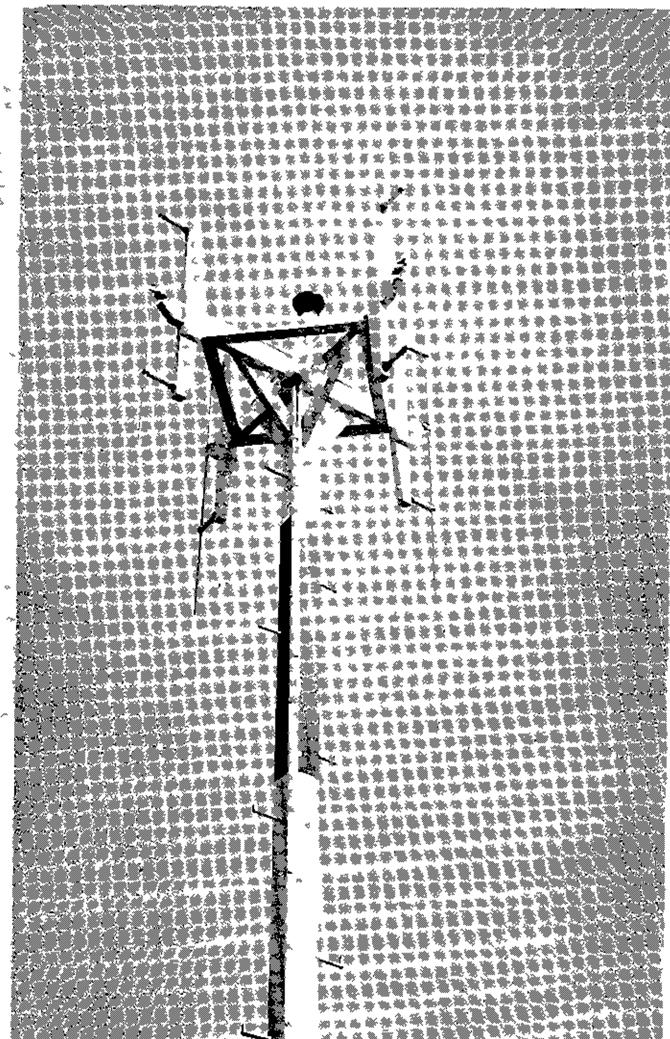

Fig.3- Close-up view of the radio range antenna system.
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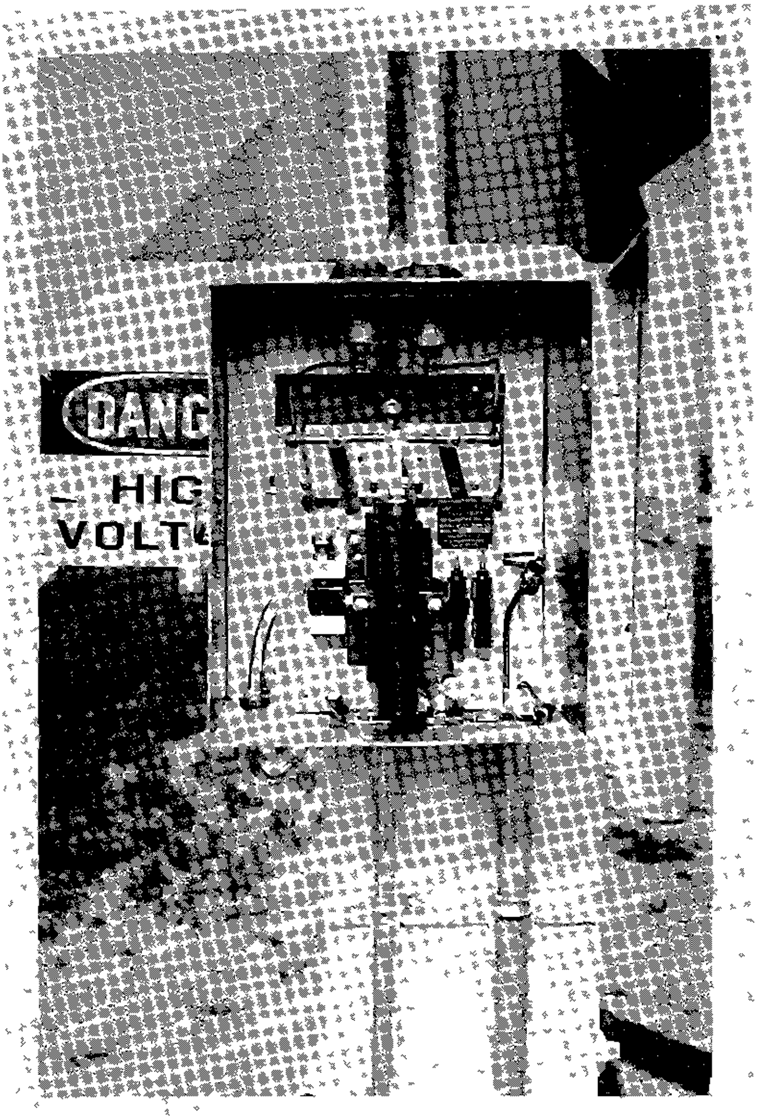

Fig.4- The modified link circuit relay mounted on pole.
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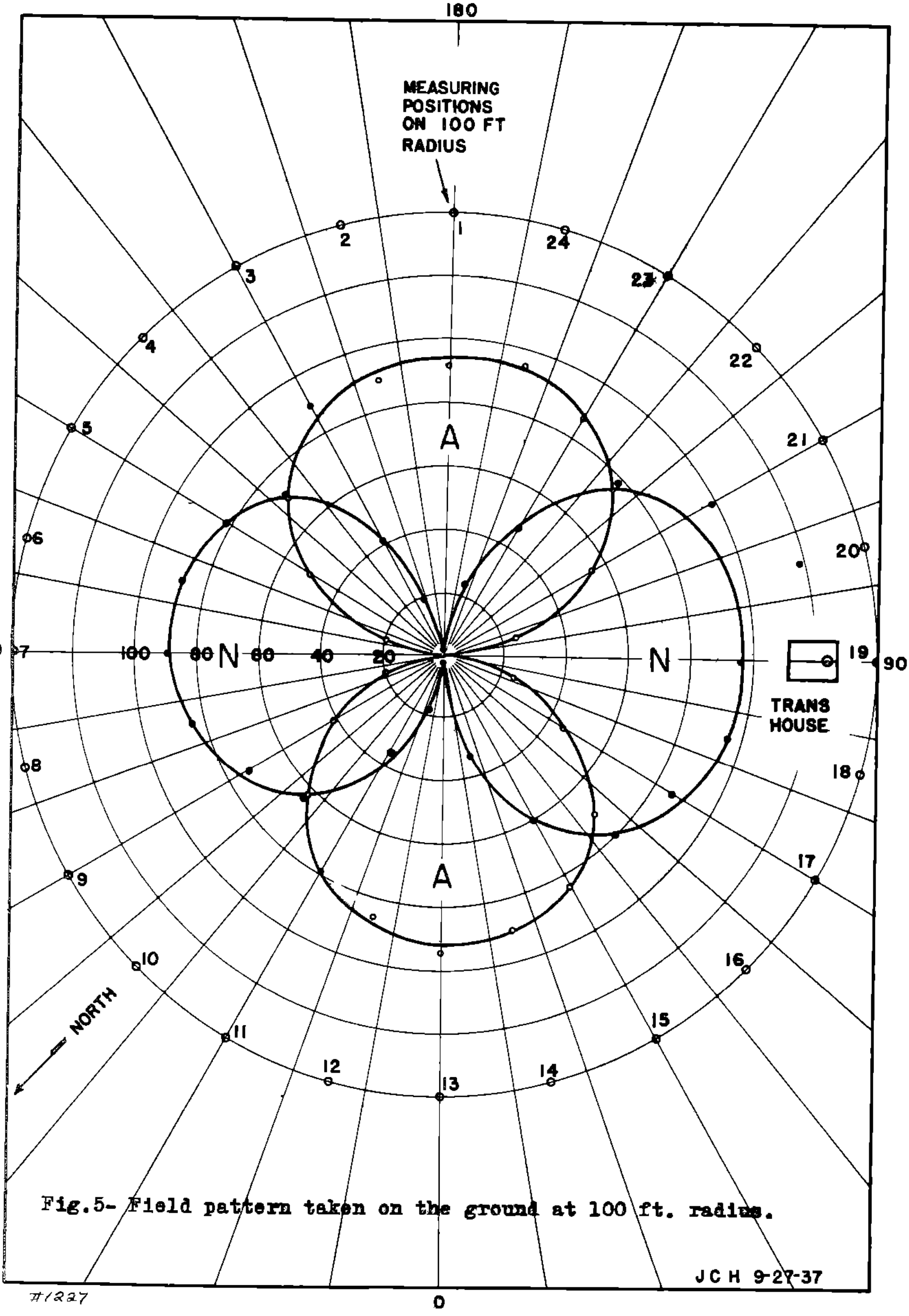

Fig.5- Field pattern taken on the ground at 100 ft. radius.

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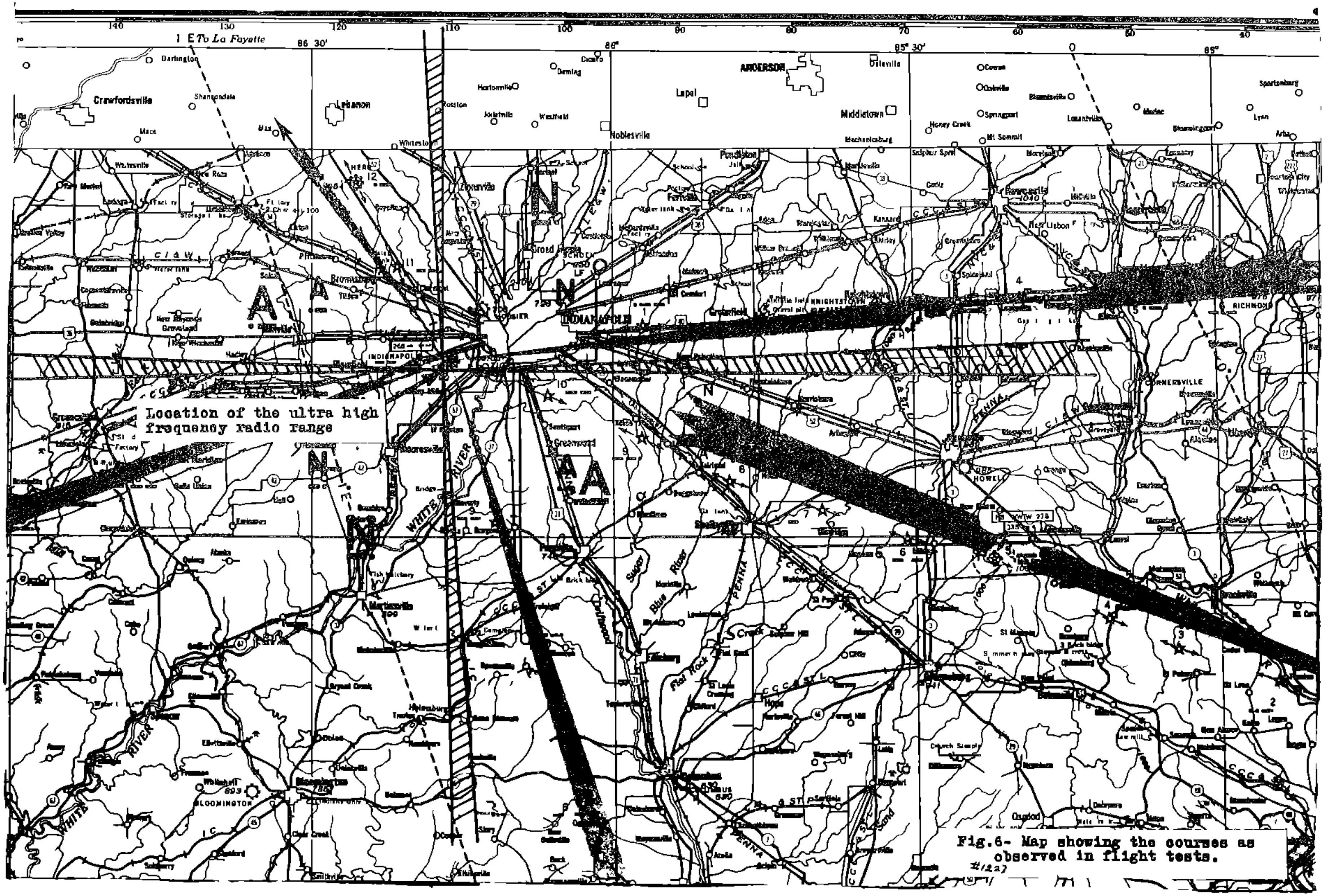

Fig.6- Map showing the courses as observed in flight tests.