CIVIL AERONAUTICS AUTHORITY
WASHINGTON

THE USE OF THE AIRWAY RADIO RANGE AND OTHER RADIO AIDS

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INTRODUCTION

Although airline transport pilots are familiar with the operation of radio aids to navigation and are experienced in their use, as demonstrated in their tests for airline transport pilot ratings, more and more aircraft are being equipped with radio sets by private owners who do not have the benefit of the instruction provided by the air carriers for their own airmen. This publication, therefore, has been prepared by the Civil Aeronautics Authority for the purpose of instructing the novice instrument and radio flyer in the fundamentals of the use of the radio aids.

The material contained herein is intended as a non-technical presentation of enough elementary theory to prepare any pilot for practical flight training in the use of radio aids on the Federal airways system.

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THE USE OF THE AIRWAY RADIO RANGE AND OTHER RADIO AIDS

It is possible for an experienced pilot to learn to follow a radio range course mechanically by observing a few simple rules without necessarily knowing the theory upon which those rules are based. It would be an entirely different matter, however, were he suddenly faced with the problem of orienting himself from an unknown position. In such circumstances it is essential that the pilot follow through to completion a predetermined plan of procedure. He must execute <u>each step in precise sequence</u>, with complete reliance upon his ability to interpret correctly the changing radio signals he receives. To do so he must be able to <u>visualize clearly</u> the manner in which radio range courses are formed.

Begin by comparing a radio range which controls the intensity of its signals in certain directions with a conventional broadcast station which normally radiates its energy with substantially the same intensity in every direction. Figure 1-A illustrates the circular shape of the pattern covering the area over which a broadcast station would be heard with an ordinary receiver. Signals are strong near the transmitter and grow weaker gradually as they spread out in all directions until they fade out entirely. The radius of this circular area (Fig. 1-A) could be considered greater or less as the receiver volume is advanced or retarded, or the transmitter power is increased or decreased.

The shape of the pattern in which signals are audible can be controlled to some extent by use of specially designed transmitting antennas, one type of which is the loop, illustrated in Fig. 2.

Comparing the pattern of the loop (Fig. 1-B)with the pattern of the broadcast antenna (Fig. 1-A) it will be found that radiation from the loop is suppressed in both directions at right angles to the loop, and maximum radiation is obtained in the directions in line with it. The loop is represented at the center of Fig. 1-B as it would appear if viewed from directly above. Note the directions in which it points by reference to the aircraft compass rose drawn around the figure. For identification purposes the signals radiated by this loop are broken up into a succession of dots and dashes corresponding to the letter "A" (dot dash) and so represent-

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ed by blocking in the areas covered by the signals. Figure 1-C represents the area which would be covered by another identical loop at the same location but rotated 90 degrees (at right angles) and transmitting a succession of letter "N"s (dash dot).

Two such loops radiating alternately would cover the areas shown in Figure 1-D. It is obvious, however, that only in the zones in which adjacent areas overlap would both the "A" and "N" signals be audible (Fig. 7).

At the landing field represented by "F" in Figure 1-D both the "A" and "N" signals would be heard with exactly equal strength, resulting in a steady monotone or "on-course" signal. This is due to the "A" and "N" signals interlocking. The same would be true at any other point on a line drawn through the center of each of the four zones of overlapping signals. It will be noted that the dash of the "N" is transmitted first, then the dot of the "A", then the dot of the "N", and then the dash of the "A" (Figure 7). It is now obvious that radio range courses are merely narrow wedgeshaped zones in which two signals of equal strength interlock and are heard as a monotone popularly called the "beam". The degree of accuracy with which the ear judges relative signal strength (particularly station identification signals) determines the accuracy with which a pilot can fly a radio range course. The course signals ("A" and "N") are broadcast for thirty seconds, when they are interrupted and the station identification signals are broadcast twice (once from each loop). Seven seconds are used to transmit the station identification signals. This results in a complete sequence every thirty-seven seconds. At present there are twelve "A"s and twelve "N"s transmitted between station identification signals.

An airplane taking off from the field (Fig. 1-D), flying away from the transmitter and following the line along which the "A" and "N" signals continue to be received with equal strength, would start with the receiver manual volume control near minimum. The signal strength would drop off rapidly at first, making it necessary to advance the manual volume control at frequent intervals. As the signal becomes progressively weaker with distance the manual volume control would have to be advanced less frequently. Eventually, the limit of receiver sensitivity would be reached or the accompanying atmospheric noises and interfering stations would become louder than the desired signal. The distance from the transmitter at which this condition occurs depends upon the power of the transmitter, the

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condition and type of receiving equipment, and the amount of atmospheric noises (static) present.

NOTE. Automatic Volume Control (A.V.C.) is unsuitable for radio range navigation due to the fact that it automatically brings in the weak signals and repels the strong signals thereby defeating the accuracy of the radio ranges. AVC would cause a pilot to hear an "on-course" signal at a point where he should hear an "off-course" signal. Using AVC the pilot could be flying away from the transmitter and not be aware of the fact because the automatic volume control was automatically turning up the volume thereby keeping the signals at the same level. It is extremely difficult to hear a cone of silence with AVC for the same reason. As the signal fades out the AVC automatically brings in the weak signal which eliminates to a great degree the possibility of getting a definite fade. The "on-course" is also considerably wider when on AVC, which is very misleading. Certain changes of signals will be heard on AVC which are entirely erroneous and will soon confuse the pilot to the point of becoming completely bewildered. Therefore, it is quite obvious that the pilot should keep the volume control switch turned to MANUAL when flying the radio ranges. It will also be noted that the radio receiver will operate as if turned on AVC when the volume is carried too high, even when the switch is turned to MANUAL.

The accuracy with which a pilot can detect a fade or change of signal depends almost entirely upon his previous training and the manner in which he handles the manual volume control. A pilot who has not had training in detecting a fade or change of signal will deviate a considerable distance to either side before his ear can detect a change of signal. This would cause the course flown to be erratic. The limits between which an airplane may range to either side before a change in signal is apparent is approximately $1\frac{1}{2}$ degrees each side of the center line. This is actually the way in which the courses are plotted on aeronautical charts. The magnetic bearing of each course in degrees toward the station is published by the Civil Aeronautics Authority for all stations, with the magnetic variation specified in each case. The use of flying charts on which all courses are plotted with magnetic bearings is explained in detail in Special Publication No. 197 of the Coast and Geodetic Survey. This publication can be procured from the Coast and Geodetic Survey, Washington, D. C., at $0.50 per copy.

Like the entertainment broadcast band, the aeronautical radio range frequency band (200-400kc.) must accommodate a great number of stations and some interference is unavoidable. To eliminate all danger of mistaken identity, each station is assigned an individual one or two letter station identification signal, which corresponds to the teletypewriter identification. As previously stated, the course signals ("A" and "N") are transmitted for thirty seconds and then the station identification signals are transmitted twice (once from each loop - from the "N" loop first and the "A" loop second) after which the course signals are resumed. Each radio range station operates on a designated frequency (i.e. 344kc., etc.). This means that only one radio range station should be received at any one place on the dial. Therefore, there are two means of identifying a radio range station. First, by the radio frequency or dial setting. Second, by the station identification signals. For instance, the pilot wishes to tune in the radio range station at Burbank, California. He knows that the radio frequency is 260 kc. and that the station identification signals are B-U (-... ..-). He turns the radio dial to 260 and receives a signal. He waits until the station identification signals are transmitted and reads them as B-U (-... ..-). This has definitely established the fact that he is listening to the Burbank station.

When a pilot is flying away from a range station, the farther he progresses the less accurately does he know his position, but if he follows any one of the four courses toward the station he will be led to a definite point. That point can be identified aurally by what is usually termed the "cone of silence". The "cone of silence" is an area normally directly above the station, in which all signals fade out when the airplane passes directly through it. It should not be confused with the momentary "fade-out" of signals sometimes found along airways resulting from other causes, since it will be observed that just before arriving at the "cone of silence" the signal volume builds up rapidly and it will be necessary to turn the volume down several times in the last mile. Upon arrival at the "cone of silence" the signal is observed to suddenly fade out for a few seconds, depending on the speed and altitude, and then surge back with still greater volume than before. Unless the receiver volume is kept at a minimum value and the airplane is exactly "on-course" when passing over the station the signal will not fade completely out. Some pilots have complained that even when they flew over the station by "contact" and were positive that they were directly over the station they did not get a fade-out of signals. This would be true if the antenna installation on the airplane were not correct or the radio receiver switch were turned to AVC. Figure 3 shows the normal position and shape of the "cone of silence" over a loop station.

The pilot should have a complete understanding of the inherent limitations of each radio range he intends to fly before attempting to fly them during inclement weather. Range courses which theoretically should be perfectly straight may be found to have kinks or bends. This is most likely to occur where the courses pass close to or over hilly or mountainous terrain, large bodies of water, or over mineral deposits. Under such conditions a course is sometimes broken up into several parallel courses, usually referred to as "multiple courses". "Multiple courses" are extremely difficult to follow due to their being very narrow and usually very erratic. They are very confusing to the average pilot who has had limited experience with them. A multiple may have the same signals on both sides or may have the normal signals on either side or may have the signals reversed. It is recommended that reference be made to the Air Commerce Bulletin, Volume 6, Number 3 and Volume 8, Number 3, for important discussions on the observation of multiple courses at Salt Lake City, Utah and at Los Angeles, California. Bent courses sometimes called "dog-leg courses" are usually of little consequence since the bend is generally small and away from and around the obstruction that caused it. However, in mountainous country bends have frequently been found that necessitated a change of compass heading of 45 degrees for a short distance in order to stay on course. Several such bends may occur on a range in a short distance. Obviously such a range would be hazardous to a pilot who was not familiar with that particular range and its peculiarities. These conditions may be found anywhere but are generally confined to hilly or mountainous terrain. A bent course creates the impression that the course is swinging if the airplane proceeds on a straight line. Theoretically, the only time that courses actually do swing from their fixed position is usually for a short period at sunrise and sunset. This has been almost entirely overcome by substituting for the loop antennae a system of four steel tower radiators, located at the four corners of a large square plot and fed from a transmitter in the center through underground transmission lines. However, the signals are transmitted in the same manner as in the loop type stations.

Electrical or mechanical breakdown of the transmitting equipment could cause complete failure, or more serious yet, a condition which might for the moment be mistaken for an on-course signal where none should exist. Every conceivable precaution is taken to prevent failure of radio ranges by frequent regular inspection, cleaning and overhaul. In addition, a monitoring system is maintained. Not one, but several, receiving stations are charged with the responsibility of listening to each range for evidence of course deviation or other fault. Any departure from normal is investigated immediately and warnings broadcast to all concerned.

Other peculiarities may be observed such as a "leaning" cone of silence, or inability to hear a range as far as expected. This may occur where courses are not 90 degrees apart. Investigation usually reveals that one or more of the four courses were intentionally shifted from the normal 90 degree alignment when the station was originally tuned. Such changes are necessary to make certain courses coincide with the civil airways or line in some other desired direction. These changes could be accomplished by rotating the loop transmitting antenna or relocating the tower radiators, as the case may be, but in actual practice the same result is more conveniently achieved electrically by merely readjusting the transmitting apparatus.

In most cases 90 degree separation of courses will not bring them all in the desired alignment. Generally, there are two methods of displacing courses from their normal 90 degree separation. One is termed "course shifting" and is illustrated in Figure 4. The theoretical explanation of shifting (sometimes called "squeezing") of the courses may be visualized by plotting the pattern of the areas covered by signals from each loop and noting the resulting displacement of the on-course zones when the relative size of adjacent patterns is changed. The size of these areas is, of course, governed by the power radiated from the corresponding loops. The heavy dotted lines in the illustration represent the pattern after adjusting the transmitting equipment for this purpose. It will be noted, incidentally, that any displacement of the course is achieved at the expense of a corresponding reduction of the distance over which the displaced courses may be used.

After shifting courses in the manner described above, opposite or reciprocal courses remain 180 degrees apart. Occasionally circumstances demand a bend in reciprocal courses. This is accomplished by altering the relative size of the patterns in such a manner as to produce the desired alignment. (An example is illustrated in Figure 5.) This alteration is obtained not by a reduction of current in the loop, but by cancellation of a portion of the radiated energy.

Marker Beacons
Class "M"

A class "M" marker beacon is a low-powered, non-directive radio station which transmits a characteristic signal, such as "H" (....) once every ten or twelve seconds. Class "M" marker beacons are normally equipped for voice communications with aircraft. These marker beacons have a range of from three to ten miles depending on the weather conditions and the type and condition of receiving equipment being used. Marker beacons are normally placed at the intersection of two range courses indicating when to tune to the next station. In such a case the characteristic signals are transmitted on the same frequencies as the adjacent radio ranges so that they can be heard if the receiver is tuned to either range. Marker beacons may also be placed on or near some obstruction, such as a radio tower, or at some particular point along the airway. A marker beacon does not operate continuously, but is turned on when the local ceiling is less than "unlimited" and/or when the visibility is less than two miles, or at any time on request. This is because a marker beacon is used by the pilot to check his position when flying "over the top" when the ground cannot be seen. A pilot reporting over a marker beacon sets the manual volume control at a comfortable level and notes the time on his clock when he first hears the marker beacon. Suppose it was 10:00 A.M. when the signal was first heard. The pilot does not move the volume control either way but leaves it set as it was when he first heard the signal. The last marker beacon was heard at 10:10 A.M. The pilot reports his position as "over ____ marker at 10:05".

A properly qualified pilot, preparing to take off for a cross-country flight in an instrument-equipped aircraft and expecting to use the available radio facilities, files his flight plan with the airway traffic control station of the Authority, if there is such a station on the airport where he is preparing to take off, or the air-traffic control-tower (airport traffic control tower), or in person, by telephone, teletype, telegraph or radio to the nearest teletypewriter station of the Authority. (Approval of a flight plan, traffic control instructions, and any flight plan amendments must be received from the airway traffic control station of the Authority if the pilot departs from an airport within, or at any time plans to enter, the area in that vicinity controlled by such station.)

In the use of two-way radio, it is important that conversation be kept to a minimum, because the operator on the ground can talk to only one pilot at a time. If some pilot is using the channel unnecessarily, he may be keeping valuable information from some other pilot who is in dire need of it. When a pilot flies cross-country, he checks the fuel and oil tanks, he checks the engines and radio, and he checks the weather. It is obvious that he should also check the maps. The maps should be brought up to date by referring to the bulletins published by the Civil Aeronautics Authority for that purpose. He should bisect the quadrants and get the average bisectors for the "A" and "N" quadrants of the radio ranges along the route he plans to fly; secure information such as the peculiarities of those ranges, if any; learn the magnetic bearings of the ranges, and the relation of the radio range station to the airport; know the dial settings and station identification signals of all stations along and adjacent to the route so as to eliminate any unnecessary work in the event that during the time of weather broadcast he should get lost or should he, at any time, be compelled to fly with reduced visibility. A small amount of work along these lines will eliminate a great many difficulties.

Orientation

When lost in the vicinity of a radio range station the pilot should immediately adopt a plan of action and follow it through to completion, executing each step in precise sequence with complete reliance upon his ability to interpret correctly the changing radio signals he receives. He should be capable of visualizing his approximate possible positions with relation to the radio station, but should not assume that he is in a particular position. He should adopt a course which is parallel to the average bisectors of the quadrants or a course which is perpendicular (right angles) to the average bisectors of the quadrants depending upon which method of orientation is being used.

NOTE: The word "bisect" means to divide in half. In bisecting a quadrant which has a spread of 60 degrees between the two "on-course" zones, the bisector will be a point midway between the two "on-course" zones or at a point 30 degrees from each "on-course" zone.

By referring to Figure 6 we find that the north "N" quadrant has a spread of 80 degrees from 333 degrees to 53 degrees. It will be noted that the bisecting course for the north "N" quadrant is 13 degrees or

193 degrees depending on whether the pilot is flying toward or away from the station. This course is known as the bisecting course of the north "N" quadrant. It will be noted that the southern "N" quadrant has a spread of 72 degrees, from 270 degrees to 198 degrees. The bisector of this quadrant is 54 degrees or 234 degrees, depending on whether the pilot is flying toward or away from the station. It is obvious that if a pilot is lost he should never assume that he is in a certain position. Therefore, a course must be flown which will be applicable to either quadrant. This is accomplished by laying a straight edged ruler across the map and, by reference to a compass rose, noting the average bisecting course. The average bisecting course is found to be 35 degrees or 215 degrees for all practical purposes. Since the average bisecting courses of radio range stations are always 90 degrees apart the average bisecting courses for this station are 35 degrees or 215 degrees in the "N" quadrants and 125 degrees or 305 degrees in the "A" quadrants.

The following are a few simple but important rules that should be memorized by all pilots who anticipate flying the radio range:

Rule. 1. The northern "N" quadrant is the quadrant in which True North lies. Since the "N" quadrants are diametrically opposite, this rule immediately establishes which are the "A" and "N" quadrants. When the bearing of the northern range course happens to be True North, the quadrant to the West of this north course will be the "N" quadrant.

Rule. 2. The first station identification signal is transmitted in the "N" quadrants, the second in the "A" quadrants, the opposite of the alphabet. Figure 7.

Rule. 3. If two station identification signals are heard, one being louder than the other, it is obvious that the pilot is near some "on-course" zone. (Figure 7). If the weak station identification signal starts to fade out it is obvious that the pilot is flying away from the nearest "on-course" zone. If the weak station identification signal gets louder, the pilot is flying towards the nearest "on-course" zone. It will be noted that when "on-course" both station identification signals are heard with equal intensity. This information is particularly valuable when the volume is

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increasing and fading so as to make it difficult to tell by sound whether the pilot is flying toward or away from a station. It is also valuable when static conditions make the signals almost unreadable. The volume will not change sufficiently fast to disrupt the relative intensity of the two station identification signals. Normally, rain and snow static will cause all signals to be blanketed out. Many airline transport pilots use the relative intensity of the station identification signals almost entirely as a means of following the "on-course" when they are a considerable distance from the station.

The various radio range stations have different bisectors since the "on-course" zones are pointed in different directions. It is, therefore, necessary that the pilot prepare this information in advance for each individual range he plans to fly.

It must be remembered that radio range stations are to be used strictly as an aid to dead reckoning. The pilot should not rely on the range alone, ignoring the compass and other instruments, as there is always the possibility that the range may be turned off because of mechanical difficulties or may be unintelligible due to static or other conditions such as receiving equipment being in poor condition.

Orientation by the 90 Degree Method.

In working out a problem by the 90 degree method, a compass course is flown which is at right angles to the average bisector of the "A" or "N" quadrants, depending upon which signal the pilot is receiving. This means that the pilot can fly one of two directions in the "A" quadrants, or one of two directions in the "N" quadrants. In Figure 8, the range courses toward the station are NE 240°, SE 330°, SW 60°, NW 150°. The right angle or perpendicular to the average bisector of the "A" quadrants is found to be 15° or 195°. The right angle or perpendicular to the average bisector of the "N" quadrants is found to be 105° or 285°. The courses 15° or 195° are the only two headings that can be flown in an "A" quadrant on this particular pattern using this method. Assuming that the signal being received is an "A", the pilot turns to the nearest of these two headings. If when he turns on his radio two

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station identification signals are heard, the first one weak and the second one loud, he knows that he is in the vicinity of some one of the four "on-course" zones, but is aware that he can be in any one of the four situations with reference to courses and average bisectors, as noted by positions 1, 2, 3 and 4 in Figure 8. Assuming that he turns to a heading of 15°, he immediately eliminates the southeast and the southwest "on-course" zones, which are behind him. He knows that if he flies 15° there are only two "on-course" zones that can possibly be encountered; that is, the northwest or northeast "on-course"zones. Remember, there are two station identification signals, the first one weak and the second one loud. He flies this compass course for two or three minutes and notices that the weak station identification gets weaker. That immediately tells him he is flying away from the nearest "on-course" zone, and that he might have to fly as long as fifteen or twenty minutes to pick up the "on-course" zone now in front of him. He makes a 180° turn and flies 195° (position 3 and 4 Figure 8). He notices that the first station identification signal, which was the weaker, begins to get louder. In flying 195° he has eliminated the northwest and northeast "on-course" zoner, and is now only concerned with the southeast and southwest "on-course" zones. (The map should always be held parallel to the direction of flight so as to avoid becoming confused).

The pilot continues flying 195° until he encounters the "on-course" zone. He flies through the "on-course" to the other side. On the first "N" signal on the other side of the "on-course" he makes a time turn of 90° to the right and immediately corrects to the proper compass heading in case this turn was not exact. He flies in the new direction for approximately one minute. It will be noticed that if he is in position No. 4, after making this 90° turn, he goes definitely into an "N" and definitely away from the "on-course" zone. The pilot continues flying 195° until he encounters the "on-course" zone. He flies through the "on-course" to the other side. On the first "N" signal on the other side of the "on-course" he makes a time turn of 90° to the right and immediately corrects to the proper compass heading in case this turn was not exact. He flies in the new direction for approximately one minute. It will be noticed that if he is in position No. 4, after making this 90° turn, he goes definitely into an "N" and definitely away from the "on-course" zone. He knows at once which "on-course" he has crossed because had he been in position No. 3, he would have immediately gone back into the "on-course" and into an "A" after making the 90° right hand turn. On flying from an "A" to an"on-course" and back to an "A", a turn of 180° should be made to the left. In flying from an "A" to an "on-course"and into an "N", a turn of 270° should be made to the left. Remember, "A" to "A" or like to like - 180° left. "A" to "N" or like to unlike - 270° left. The purpose of this turn is to get back to the "on-course" at such an angle that a turn of approximately 45° to the left will place the pilot on the proper course to stay in the "on-course" zone. The pilot then locates the right-hand edge of the "beam" by sound. As soon as the edge is picked up the pilot corrects to the proper compass course of that leg of the station which is 330°. If there is a wind, he will drift into the "beam" or away from the "beam" unless he stays on the "beam edge" by sound, noting the compass correction necessary to stay on the "beam edge". The compass course of that leg of the station and the compass heading required to stay on the "beam edge" indicate to a great degree the direction and velocity of the wind.

It must be remembered that in flying an orientation problem by this method, two courses are immediately eliminated, and the right-hand turn after encountering the "on-course" eliminates another, which leaves only one course to fly. Strict attention must be paid to the station identification signals and their relative intensity.

The 90° method is worked by following four simple rules as follows:

1. Fly perpendicular to the average bisector of the quadrants you are in.

2. Upon intersection of opposite edge of the "beam", turn 90° to the <u>right</u>.

3. When quadrant signals change as a result of right turn , make a turn of 270° left and upon reaching opposite edge of "beam" turn 45° left.

4. When quadrant signals do <u>not</u> change as a result of right turn, make a turn of 180° left and upon reaching opposite edge of "beam" turn 45° left.

Follow "on-course" to the station.

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There are several occasions when the 90° method is unsatisfactory, and for this reason other methods have been devised. One example of unsatisfactory application is in a wide quadrant with a strong wind from the station. Another is an irregular angle station with the pilot on the right of the station and a strong tail wind. Here the pilot would be blown away from the "beam" into the quadrant ahead of his original course instead of back into the quadrant he had just left, thereby giving him the impression that he was to the left of the station. With the pilot on the left of the station a strong head wind will blow the pilot back into the sector he has just left when he makes the 90° right turn, which would indicate to the pilot that he was to the right of the station. (Figure 8).

The Fade-Out Method

Using the fade-out method, the pilot makes use of the subsequent intensity of the signals to determine which quadrant he is in. The pilot flies the average bisecting course of the two "A" or "N" quadrants depending on which signal he is receiving, and listens particularly to the volume, noting whether the volume is increasing or decreasing. This identifies the quadrant. Care must be taken to fly the average bisecting course long enough to get a definite fade-out or a definite build-up of signal strength. If the signal fades it is advisable to turn the volume up and wait for a second fade to make sure that the first fade was not a false fade which would possibly cause the pilot to make an incorrect decision. The pilot must turn down the volume as low as possible and still identify the signal. If he is flying away from the station the signal will fade out completely, and he will not hear it at all unless the volume is turned up. If he is flying toward the station the volume will build up and the pilot will have to keep turning the volume down to keep the sound at the same level.

CAUTION: DO NOT USE AUTOMATIC VOLUME CONTROL (AVC).

The average bisecting course takes the airplane generally away from or toward the station. The resulting increase or decrease of signal intensity, together with the direction the pilot is flying, determines the quadrant in which the airplane is flying. This method normally requires less time to work out a problem than the 90° method, but due to the fact that the volume may be variable, increasing and fading out rapidly, the pilot may have to fly as long as fifteen or twenty minutes in one direction in order to determine whether the volume is actually increasing or fading. This is especially true in a slow airplane. If such a condition prevails, it is obvious that the fade-out method would not be entirely satisfactory, due to the fact that the very basis of the fade-out method is the subsequent intensity of the signal.

However, should two station identification signals be heard at the start of the problem, one loud and one weak, and the weak station identification signal fade out, it is obvious that the pilot is flying away from the station as well as away from the nearest "on-course". The opposite is also true. As soon as the pilot has determined which quadrant he is in, he turns 180° if necessary and flies the average bisecting course towards the station. He encounters the "on-course" and flies through the "on-course" to the other side. Upon hearing the first opposite signal, the pilot makes a standard turn to the left but does not exceed 180° of turn. As soon as the pilot hears the "on-course" building up in the background he starts a turn to the right in order to arrive at the "beam edge" parallel to the "on-course". Usually, the pilot will miss the "beam edge" and will have to make several corrections by getting a bracket on the headings in order to get on the "beam edge". The volume is then turned down to the practical minimum and it is noticed whether the volume is building up or fading out. If the volume is building up, the airplane is headed toward the station. If the volume is fading out the airplane is headed away from the station, whereupon a procedure turn is made and the station is approached. On a station having 90° separation of courses, the compass heading will also identify the leg of the station BUT IF THE COURSES ARE SQUEEZED OR BENT THE COMPASS HEADING CANNOT BE RELIED ON TO IDENTIFY THE "BEAM", DUE TO THE DRIFT INVOLVED IN A HIGH WIND.

CAUTION: If in flying the average bisectors, the volume increases rapidly and only one station identification signal is heard, it is obvious that the airplane is in the center or

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near the center of the quadrant. Also it would be obvious that the "on-course" will be intersected so close to the station that it would be impossible to get on the "on-course" in time to pick up the "cone of silence". In a case of this kind, the fade-out method should be abandoned and the parallel method employed as described in the next paragraph. (Figure 9).

Parallel Method

The parallel method is so named because after identifying the quadrant in the same manner as in the fade-out method, the pilot flies parallel to one "on-course" to intercept another "on-course". This method is closely associated with the fade-out method and the procedure to identify the quadrant is exactly the same. However, after the pilot has identified the quadrant he selects the "on-course" he desires to fly to the station. This selection may be highly desirable due to obstructions on a certain leg, strong winds, or a given leg may be the initial approach for that station. After the pilot has selected the "on-course" he desires to fly to the station he then flies parallel to the other "on-course" forming the quadrant until he intercepts the desired "on-course" and then flies the "beam edge" to the station by sound.

CAUTION: On range stations having wide quadrants, considerable difficulty will be encountered if the pilot starts to parallel an "on-course" too soon, particularly if there is a strong wind from the station. (Figure 10).

Combination Method

The combination method utilizes all of the information given by the 90° method, the fade-out method, and the parallel method. Namely; the changes of signals, the changes of volume, and elimination of "beams" by adopting certain compass headings. The courses flown are as follows: When flying in an "A", fly 80°. If the signal fades out make a turn of 180° and fly the reciprocal heading. When flying in an "N", fly 350°. If the signal fades out, make a turn of 180° and fly the reciprocal heading. From this point on the method is the same as the fade-out method. The reason that these courses were selected was that it was found that <u>the courses 80° and 350°</u> are the <u>average bisectors of all average bisectors, of all stations</u>. This method is recommended <u>only</u> as an <u>emergency</u> method to be used when maps are blown out of the cockpit or have been left behind, or when the pilot is suddenly confronted with the problem of orientation on a strange station of which he does not have a map. It is particularly important that all turns, while flying by the fade-out, parallel or combination methods, be made on the "beam" by sound. Considerable practice will be found necessary before accuracy is obtained.

Special Orientation

Lost at or Near the Station

When the pilot becomes lost directly over the station or so close to the station that the signals are changing so fast that he cannot work a standard problem, the following is suggested: He should fly straight for a few seconds and then turn to the nearest bisector and hold this new heading for at least five minutes. By noting the fade of the signals he should be able to identify the quadrant. He can then select a "beam", turn to it, and follow it to the station.

On-Course Orientation

When the pilot turns on his radio and finds himself "on-course" he should turn to the nearest average bisecting course until the edge of the "beam" is found. The "beam edge" is followed by turning to the left in the same manner as in the fade-out and the "beam" identified.

Relative Tuning

When a pilot becomes lost a considerable distance from the station he may orient himself by relative tuning. Two or more radio range stations are tuned in other than the station that the pilot is working, and the signal from each is noted, (together with the signal intensity), and plotted, either mentally or on paper. This will, in many cases, generally establish the quadrant in which the pilot is flying.

Radio Compass

The radio compass, as used at the present time, consists of a radio receiver equipped with a loop receiving antenna and a visual right-left indicator which indicates whether the airplane

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is headed directly toward or away from the station to which the receiver is tuned, or is headed to the right or left of the station.

Radio Compass as a Homing Device

A radio compass will give a zero indication when headed directly towards or away from the station to which it is turned. In order to eliminate the possibility of 180° ambiguity, when the station is "tuned in", the pilot starts a turn to the left and continues the left turn until the needle moves from right to center. This definitely indicates that the pilot is headed toward the station.

CAUTION: PARTICULAR ATTENTION MUST BE PAID TO THE ROTABLE LOOP AZIMUTH SCALE INDICATOR. THIS AZIMUTH SCALE INDICATOR MUST BE SET AT ZERO IN ORDER TO "HOME" DIRECTLY TO A STATION.

From this point on to the station a left needle indication is corrected by a right turn and a right needle indication is corrected by a left turn. This is called "turn and bank" sensing. If when the station is "tuned in"the needle is in the center, the pilot makes a small correction to the left or right and notes which way the needle moves. If the needle moves with the rudder the station is ahead. If the needle moves opposite the rudder the station is behind. If the radio compass has a sensitivity control for the needle, the following procedure should be followed after heading toward the station: Turn the airplane 45° to the right or left and adjust the radio compass pointer sensitivity so that the needle gives a full scale indication but does not hit the stop. Recenter the needle by turning the airplane. The aural volume control should be set at a corresponding position. As the station is approached it will be necessary to turn the volume down and the compass sensitivity control should be turned down a corresponding amount to keep the needle from becoming too sensitive. The more sensitivity the more accurate the course, but when nearing the station the needle will swing wildly from side to side as corrections are made unless the sensitivity is reduced. When the station is reached it will be noticed that the needle is very sensitive even when the volume is low, and when passing over the station the needle will swing all the way to one side. An attempt not to exceed 15 degrees bank should be made to correct the needle to center. Due to the operation of the needle being reversed this attempted correction will cause the needle to cling harder to the side. This indicates positively that the station has been passed, and the pilot should immediately return to the original gyro heading he had as he approached the station. The procedure from that point on depends on the particular problem involved.

Radio Compass in computing position, track, and ground speed.

In using the radio compass for radio navigation triangulation problems, the pilot determines his approximate position by taking bearings on various known radio stations in his vicinity. The plotted bearings of these stations will form a triangle and the apex of this triangle will indicate the position of the airplane at the time the observation was taken. After several such position checks have been taken, a line connecting the fixes will indicate the track over the ground and the ground speed.

General

In flying toward the station it is advisable to fly on the right-hand side of the "on-course". The edge on the "on-course" is that portion where a strong "on-course" signal is heard and occasionally the right-hand zone signal is heard faintly in the background. A 10° change of bearing, if made to the right from the edge of the "on-course" and held for about ten seconds, with an airplane flying at100 m.p.h., will bring the airplane definitely into the right-hand signal zone where the right-hand signal will be heard every time. The same correction, if made to the left, will take the airplane into the "on-course" signal in which the right-hand signal will not be heard at all. Flying along the edge reduces wobbling or erratic course flying and keeps the pilot on one side of the "on-course", to a great extent the possibility of collision with other aircraft thus being eliminated.

When it becomes obvious to the pilot that he is close to the station (by position of the volume control), he flies in the "on-course" to the station. He has, of course, by that time corrected for the wind and has definitely established a compass course. In case there is evidence of serious bends in the "on-course" he may be unable to stay "on-course" by sound but as a result will have to pay more attention to the compass (gyro) course than to the sound of the range. The pilot knows that he is close to the station due to the fact that the volume is turned all the way down and the signal is still coming in strong and clear. If he hears what he thinks is a "cone of silence", a slight application of right rudder will take him off the "on-course" into the right-hand signal zone. If an "A" has been on the right of the "on-course" while flying toward the station and an "A" is received when he turns out to the right, he knows that he has not yet arrived at the station; that it was a fade-out or a "fake cone of silence". However, if, when he turns out to the right, he receives an "N" he knows that it was the "cone of silence" and the station has been passed because the signals are reversed upon passing the station.

Corrections made while flying on the "on-course" near the station should be of not more than 10° and held for several seconds in order that the corrections may take effect. A small correction or series of small corrections will give much more information than one violent correction, which might cause the airplane to intersect the "on-course" at such an angle that considerable difficulty may be experienced in getting back "on-course". The pilot should be particularly careful to have every move definitely planned out in his mind, and should be very deliberate about the execution of these movements. He should always have a mental picture of his position in relation to the "on-course" and the station.

<u>All aircraft, while progressing away from radio range stations, are required to keep to the right-hand side and definitely off the "on-course" signal at all times enroute</u>.

It is obvious that the best results will be obtained if the pilot is familiar with all four systems and flies a combination of the four, depending upon the existing conditions. A pilot should practice flying the radio ranges as much as possible whenever flying cross-country, even when it is CAVU, so as to become familiar with each particular range and the accompanying problems. He should practice intersecting the "cone of silence" at every possible opportunity, until he becomes proficient. The pilot should practice flying radio range orientation problems from a lost position as frequently as possible, in order that the sequence of events will become fixed in his mind to such an extent that they will become semi-automatic. The pilot should be very deliberate about his movements and not too impatient, but should wait sufficiently long after adopting a change of procedure to get a definite indication that the change has been accomplished. He should always allow ample time for a correction to take effect. After a pilot becomes proficient in flying radio range problems, each succeeding signal gives him information and by mentally filing this information he can, within a very few minutes, orient himself with a high degree of accuracy.

This high standard of proficiency can be maintained only by constant practice and through study of the various conditions encountered.

The secret of using any system is to lay out a definite plan of action and carry it through cooly and deliberately.

Loop Orientation and Radio Direction Finders.

Because of its directional characteristic, a loop antenna can be used for determining the direction of a radio station with reference to the aircraft. Maximum signal response is obtained when the plane of the loop is in line with the line of bearing which passes through the station being received, and minimum signal response is obtained when the plane of the loop is 90° from the line of bearing through the station. Either a fixed or rotable loop may be used. Most present day aural homing devices operate with a shielded loop which can be rotated manually from the cockpit at which point a dial is also incorporated to indicate the position (azimuth) of the loop with reference to the longitudinal axis of the ship. Direction finders providing aural signals alone can be classified as "Aural Null Direction Finders", while those incorporating visual indications, as well as aural, are usually referred to as "Radio Compasses". With an electro-statically shielded loop antenna it is possible to eliminate a large percentage of precipitation static. Under precipitation static conditions, the loop should be rotated so that the plane of the loop is in line with a line of bearing through the station when maximum signal response is desired, as for example, when flying a radio beam in the usual manner; but if minimum signal response is desired (Null), then the plane of the loop may be rotated to a position 90° to the line of bearing through the station, as for example, when taking a line of bearing by the aural-null method. Under precipitation static conditions, it is more desirable to leave the loop in a position for maximum signal response.

When using the loop, (in any fixed position), if the plane is turned through a complete circle at some position distant from the range station, the signal will decrease to a minimum for fade-out on two headings of the ship. These points are the nulls and are 180° from each other.

When flying the null, with a rotable loop, it is necessary that the pointer on the azimuth scale be exactly at zero; in other words, the loop is in an athwartships position. When flying a null properly, either a slight right or left turn will produce and increase the signal. If the minimum signal (Null) as indicated by the pointer on the azimuth scale, gradually drifts off the zero reference, then the course of the aircraft should be altered to correct for this drift, always keeping the pointer at zero on the azimuth scale when the signal response is minimum (Null). With the azimuth needle set on zero position when flying the null, the station is either directly ahead or behind the plane. Methods of determining the true bearing of the station will follow.

If the volume control is advanced, the null will be sharper.

If the volume control is retarded, the null will be broader.

Increased distance from a station results in a wider null.

Inaccurate tuning broadens the null.

The most satisfactory null for homing or orientation purposes is approximately 3 to 5 degrees in width. The volume control should be adjusted to maintain the null within these limitations if the signal strength permits.

The three most commonly used methods of loop orientation are:

1. 90°. (Sometimes referred to as the angular change of bearing method.)

2. Left-right.

3. Pointer progression.

The 90° System

1. Set loop to homing position (zero on azimuth scale).

2. Turn ship to obtain a null.

3. Adjust volume control for satisfactory null width.

4. Check for center of null with azimuth (if rotable loop).

5. Set gyro to zero degrees or note compass heading.

6. Turn left to gyro heading of 270° and fly this heading for three minutes or more. (Depending on distance from the station approximately 5° or 10° change in angular bearing with relation to the station should result from this maneuver.)

7. Turn ship right to zero degrees on gyro.

8. Hold heading carefully and rotate azimuth to null position. If null bearing has shifted clockwise the station is ahead, and if it has shifted counter-clockwise, the station is behind.

The same system can be performed with a fixed loop. After flying the same 270° gyro heading for 3 minutes or more and making the turn to the right, a new null must be found by pointing the airplane; then by comparing the original heading of the null with the new gyro heading of the null, accomplish the same right or left comparison with the same ahead or behind indication. This system is described in Figure 12.

Right-Left System

1. Set loop in home or null position.

2. Turn aircraft right or left until null is obtained.

3. Adjust volume control for satisfactory null width.

4. Observe gyro or compass heading.

5. Make an exact 90° right turn. (Turn as sharply as possible without causing abrupt precession of gyro).

6. Set loop in range position. (90° to null position).

7. Fly new direction through null until signal reappears.

8. Make very shallow, slow, left turn. (5° to 10°).

9. Note whether signal increased or if null returned.

10. If null returns, station is off left wing.

11. If signal increased without null reappearing, station is off right wing. (See Figure 13.)

<u>Pointer Progression System</u>

1. Set loop in range position. (90° to null position).

2. Turn ship right or left until null is obtained.

3. Adjust volume control to satisfactory null.

4. Observe gyro or compass heading and fly a steady course.

5. Note direction or rotation of loop necessary to maintain a null signal.

6. If rotation is <u>clockwise,</u> station is off right wing.

7. If rotation is <u>counter-clockwise,</u> station is off left wing.

8. Knowing the direction of the station, a turn in that direction is made and the loop may be rotated to homing position. See Figure 14.

The null may be flown by either of two methods:

1. The directional gyro is used to determine the proper direction of a turn to return to the null. When a null is obtained the gyro is set to zero. If the signal increases, it will be noted that the gyro has wandered from

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zero. In returning to this heading of zero the null will be obtained. This only holds true under comparatively still air conditions or when heading directly toward or away from the station.

2. The easiest method, however, is to set the gyro on zero when the null is obtained, then fly this gyro setting periodically investigating the null with the loop rotator. If the null is slowly falling to the right or left (noted on the azimuth scale), a leisurely correction in heading can be made so that the null will again come on zero on the azimuth scale. Obviously, drift will result in progression of the gyro reading in one direction as the null is maintained.

It is necessary that the volume control is not radically reduced as the station is approached. Although the loop will not give a cone of silence and is definitely not recommended for this work, there will be a strong build up of signal when close to the station, after which the null disappears. Normally, no cone will be heard, but a surge may be heard.

Radio fixes with loop

In taking cross bearing with a rotable loop, null bearings on two or more stations are taken in rapid succession, and the bearings thus obtained are plotted through their respective stations. The intersection of the plotted bearings represents the location of the aircraft. If the true heading is 170°, and the null of station A is 40° to the right, and of station B, 25° to the left, it is not necessary to know whether these stations are ahead or behind you. The airplane is on a bearing of 210° true (or its reciprocal 40°) from station A, and is on a bearing of 145° true (or its reciprocal 325°) from station B. On the map draw a line having a bearing of 210° true through station A, and a line having a bearing of 145° true through station B. Where these lines intersect is the position fix. Note station B is actually behind this location. (See Figure 15).

In taking cross bearings or fixes, it is important to take bearings that intersect at large angles, preferably 30° at least, thereby lessening chance of error. Generally, a fix within a 5 mile radius for stations more than 75 miles away is considered fairly accurate. D.F. (direction finding) maps greatly simplify the process of taking cross bearings, eliminating computing of true bearings and their reciprocals, and making only deviation corrections for magnetic heading necessary.

Ultra-high frequency marker receivers

These receivers pick up signals from the new "Z" type (positive cone of silence) markers and "FM" type (fan) markers. These markers operate on a frequency of 75 megacycles (75,000 KC).

"Z" type markers are located at range stations and give a positive indication at the time a cone of silence should be received. The "Z" type marker has an antenna which produces a high intensity signal in a space immediately above the station, roughly corresponding to a cylinder. "FM" markers are located so as to give a positive indication of the user's position along the airway. The "FM" type marker has a type of antenna which produces a high intensity signal in a space immediately above the station, roughly corresponding to a thick fan. This fan is placed so that its plane is at right angles to the airway.

The signal from both the "Z" and "FM" type markers is modulated with audio tone of 3,000 cycles. This tone may be heard in the head phones when a signal is being received. The tone is not keyed at the "Z" marker stations. The tone is keyed at the "FM" type stations with a number of dashes, depending upon which leg of the range the marker is located. If the marker is on the north leg or the first leg clockwise from north, the tone is keyed with one dash. If the marker is on the second, third or fourth leg clockwise from north, it is keyed with two, three or four dashes, respectively.

Operation of this receiver will not affect either loop or beam reception. An indicating light located on the instrument panel should light to full brilliancy when a strong signal is received from either the "Z" or "FM" marker stations. The time duration of the light indication will vary for given stations due to differences in installation practices aboard different airplanes.

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Eventually it is hoped that all marker receivers will be adjusted to give the same indication under given conditions. No volume control is used on this receiver as it is fixed in sensitivity.

Automatic direction finders

Recently, experimental automatic direction finders of several types have been developed. These indicate:

1. In full automatic position, a continuous bearing toward the station.

2. Freedom from 180° ambiguity.

These compasses, however, cannot operate as a fully automatic direction finding device during conditions of heavy precipitation static, but may be altered by means of throwing a switch to provide operation with a second shielded loop, in place of the regular sense antenna, but <u>with</u> 180° ambiguity. As a result of this arrangement, continuous head phone signal is provided by this second loop, which is maintained at the position of maximum pick-up relative to the reference station.

Its greatest advantage lies, of course, in the fact that once tuned to a station it continues to indicate the direction of that station, irrespective of the heading of the airplane, whereas the loop of the ordinary radio compass must be manually adjusted to the null position whenever it is desired to take a bearing. The continuous, automatic, non-ambiguous bearing is a tremendous aid in solving problems. The relative and magnetic bearings of the range station are given at all times. It checks the cone of silence unmistakably, the pointer swinging around 180° and pointing in the opposite direction in the time it takes an airplane to cross the cone of silence. This device provides continuous, manually controlled aural signals while functioning as an automatic direction finder.

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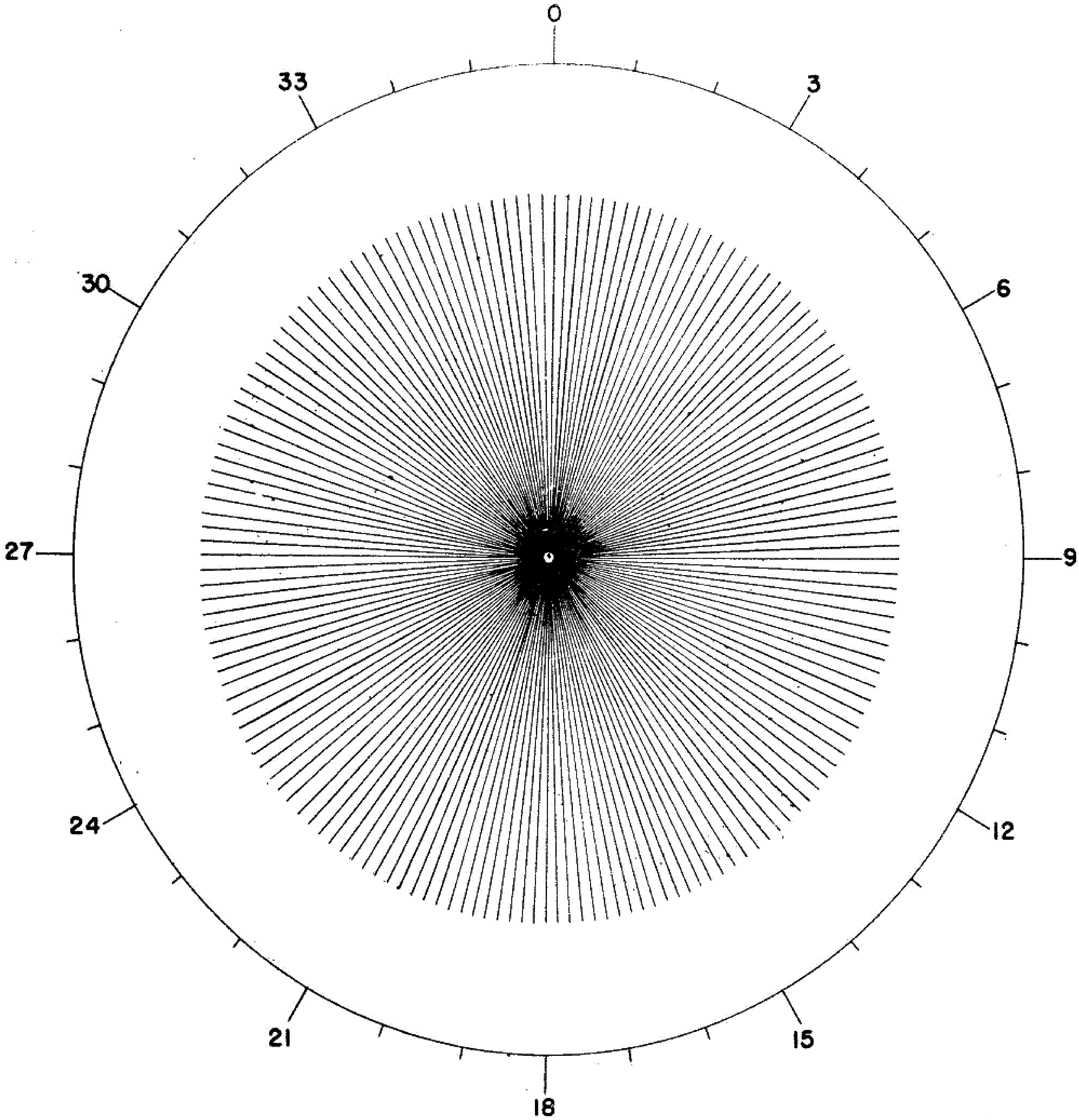

1—A

OMNI— DIRECTIONAL BROADCAST ANTENNA

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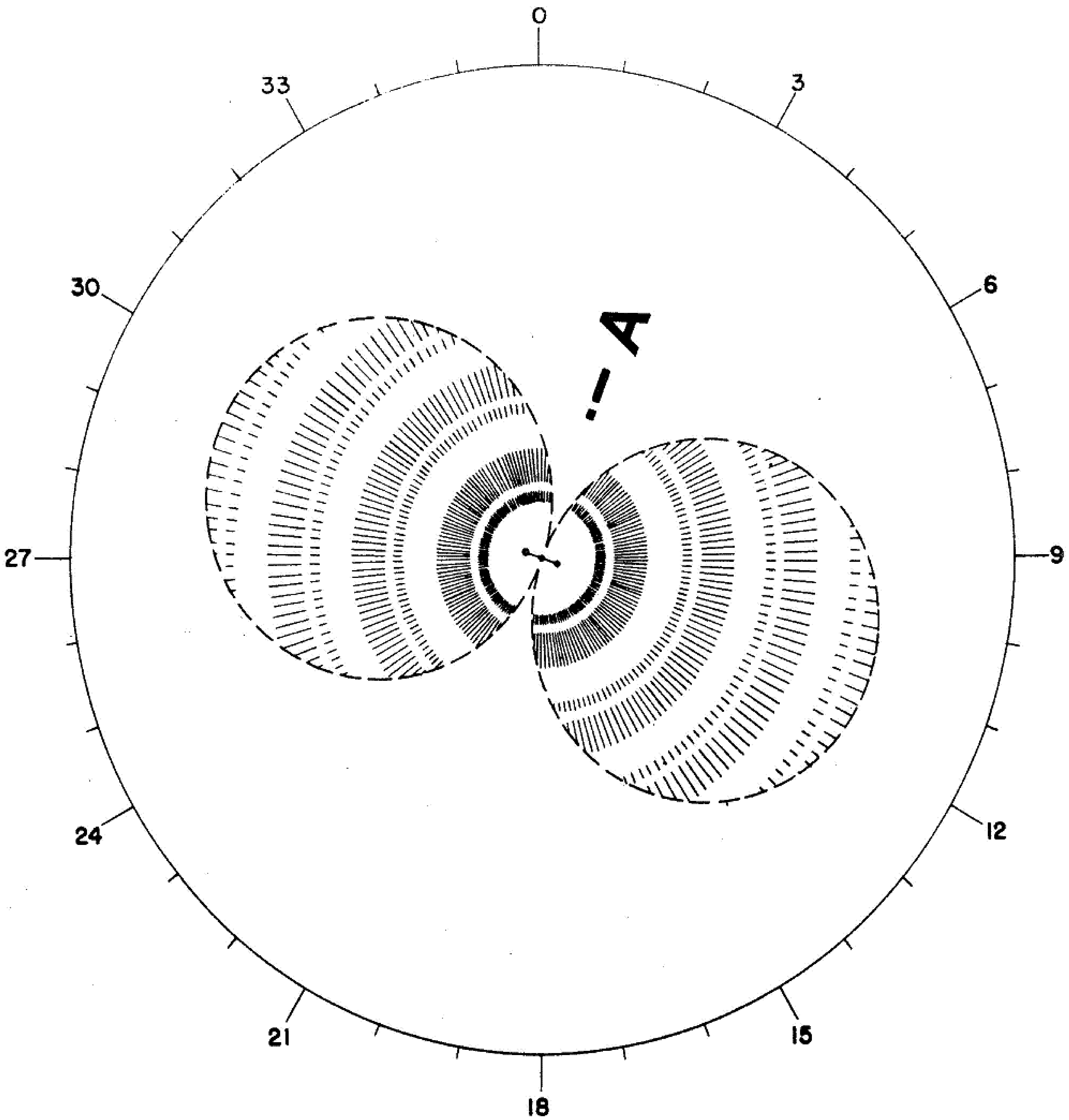

I—B

SINGLE LOOP
BEARING 100° AND 290°

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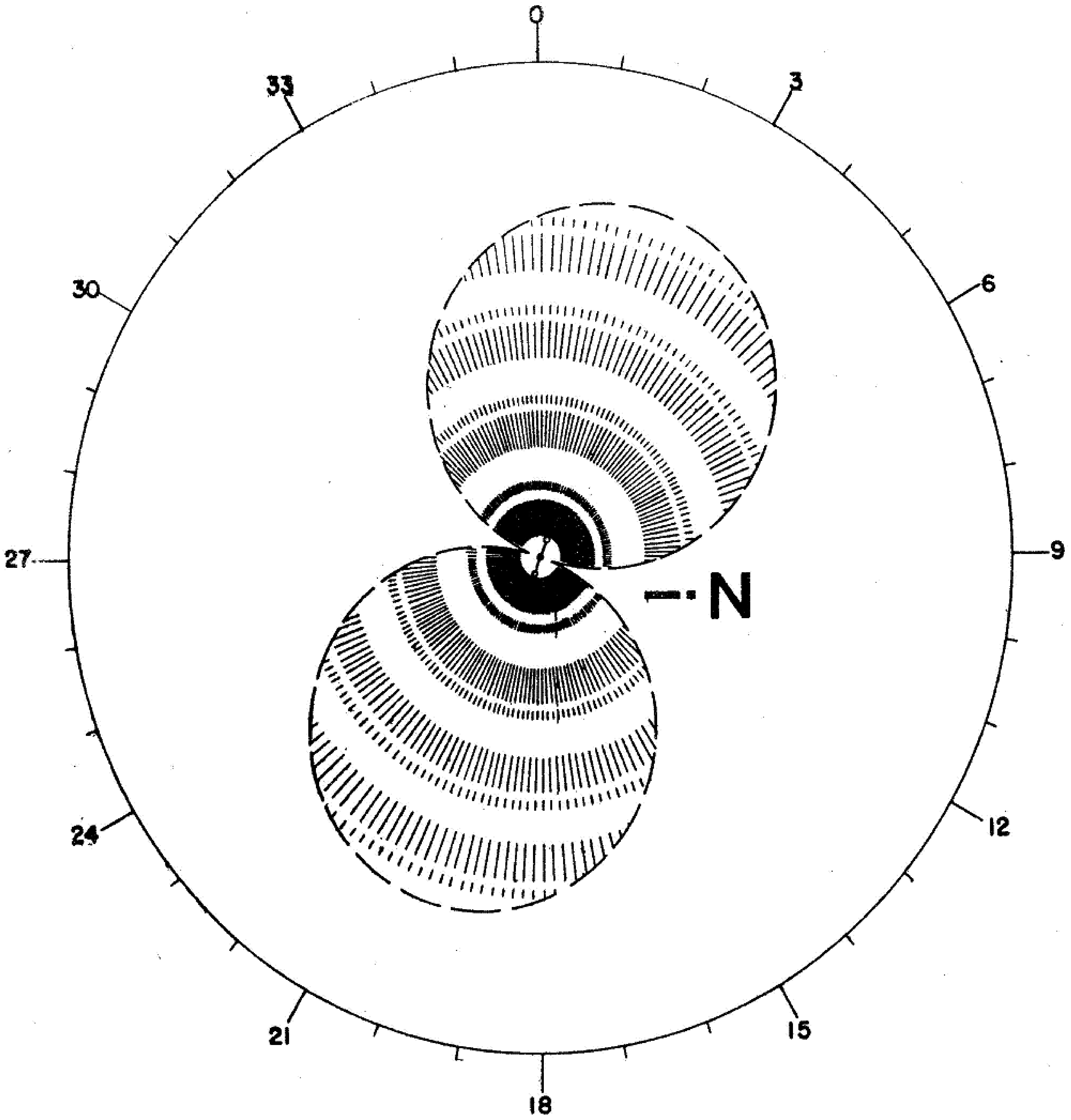

I—C

SINGLE LOOP
BEARING 20° AND 200°

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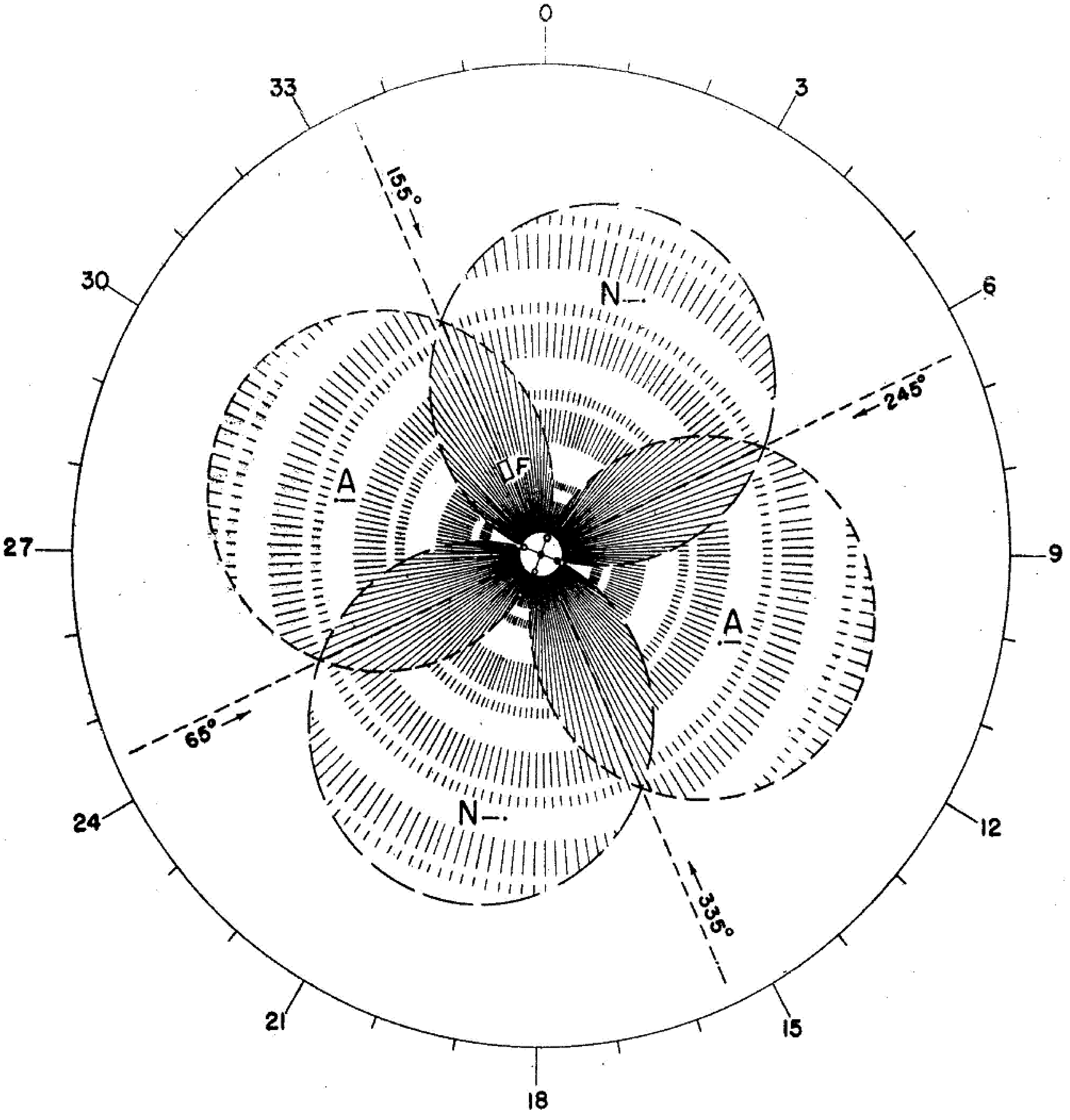

1—D

LOOPS A AND N COMBINED

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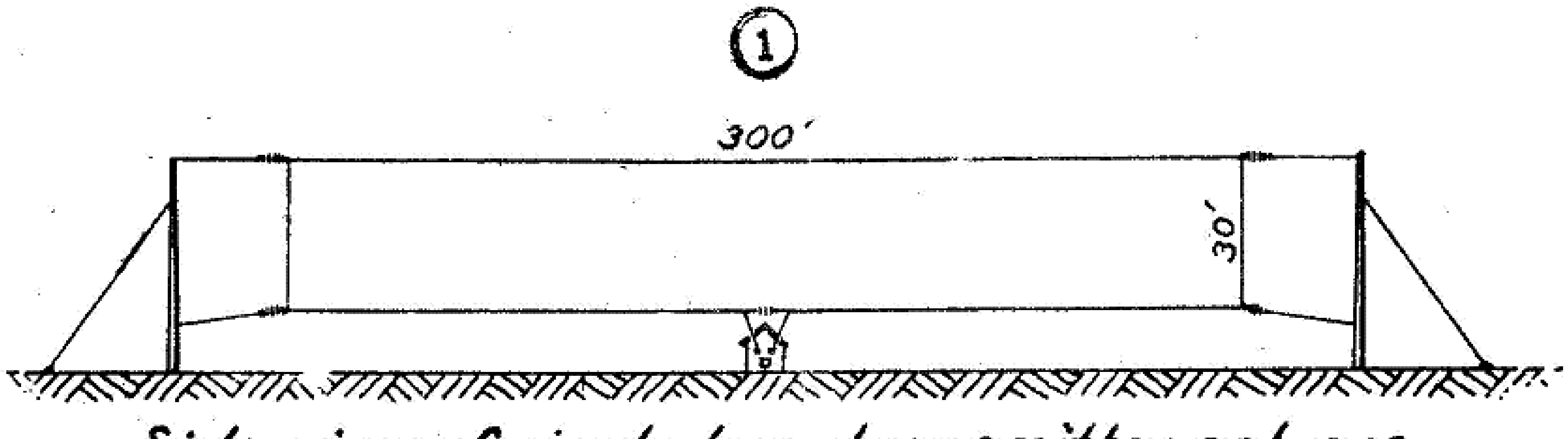
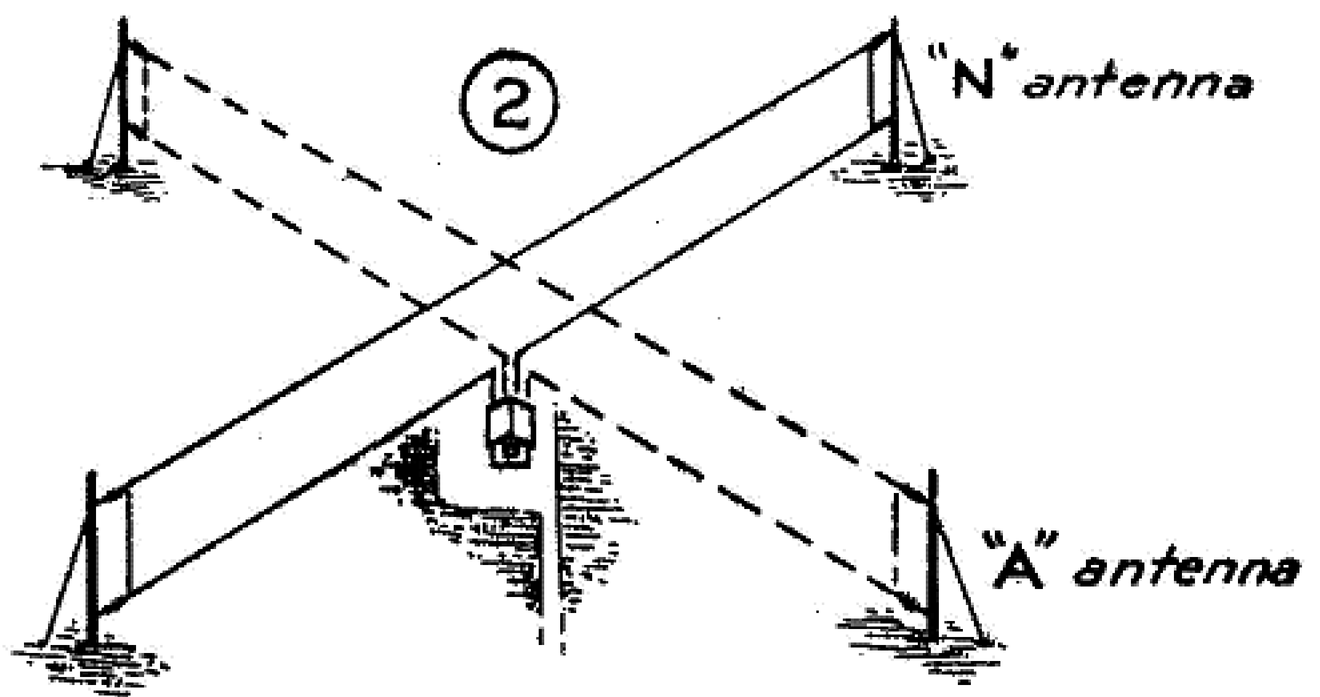
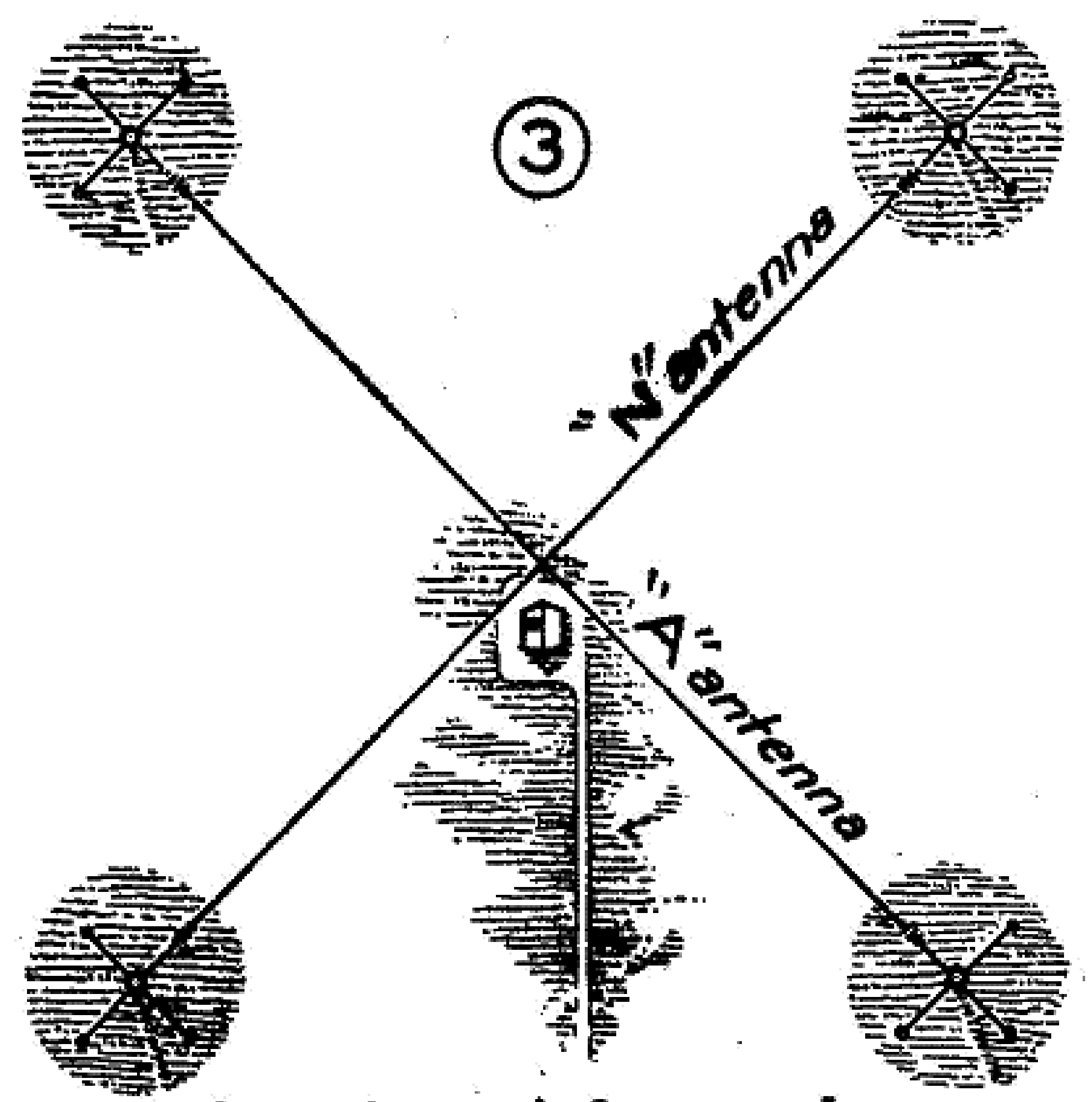


Side view of single loop transmitter antenna



Cross loops Nº 1 & 2 as used for range transmission



As viewed from above

Figure 2

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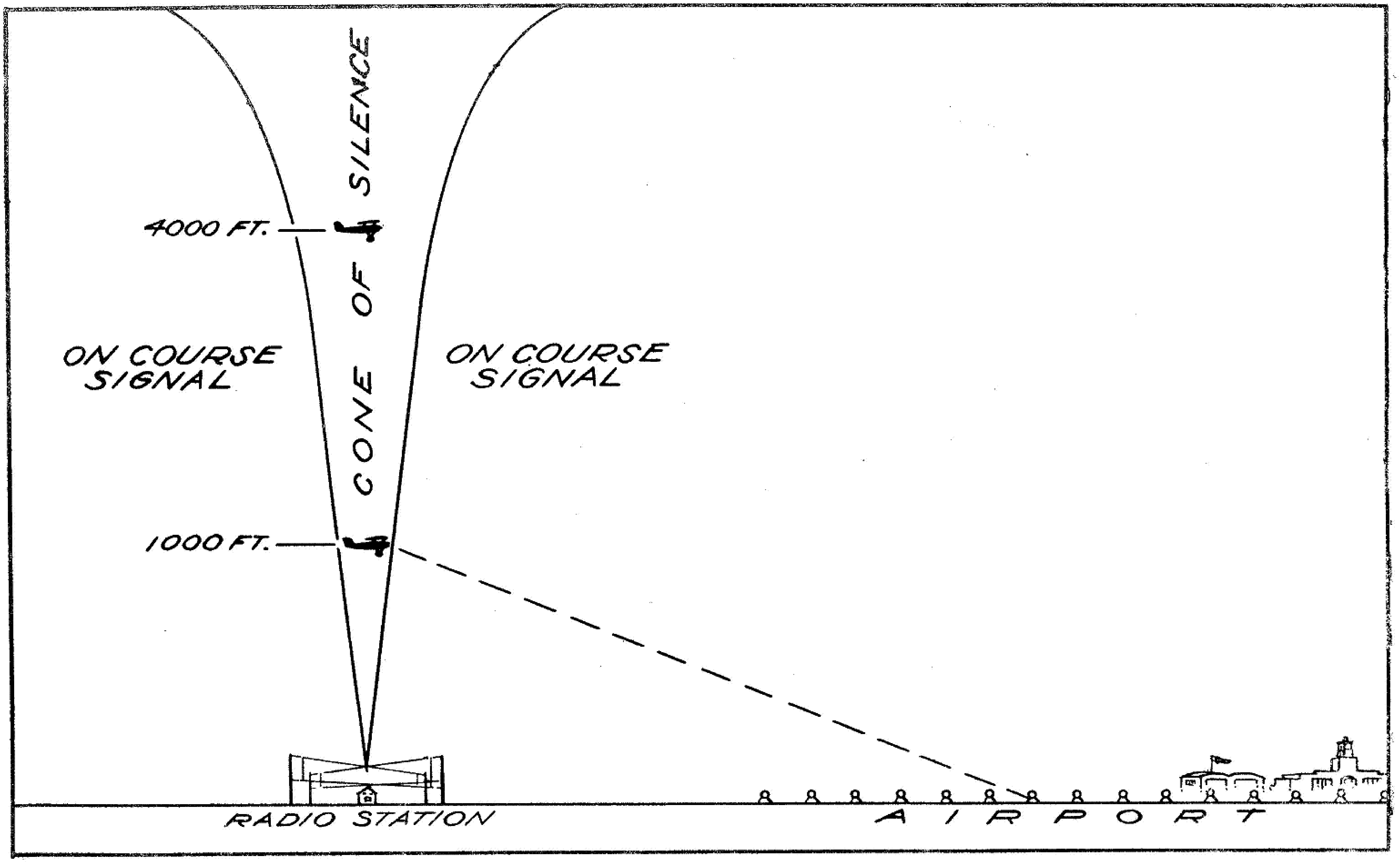

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Figure 3

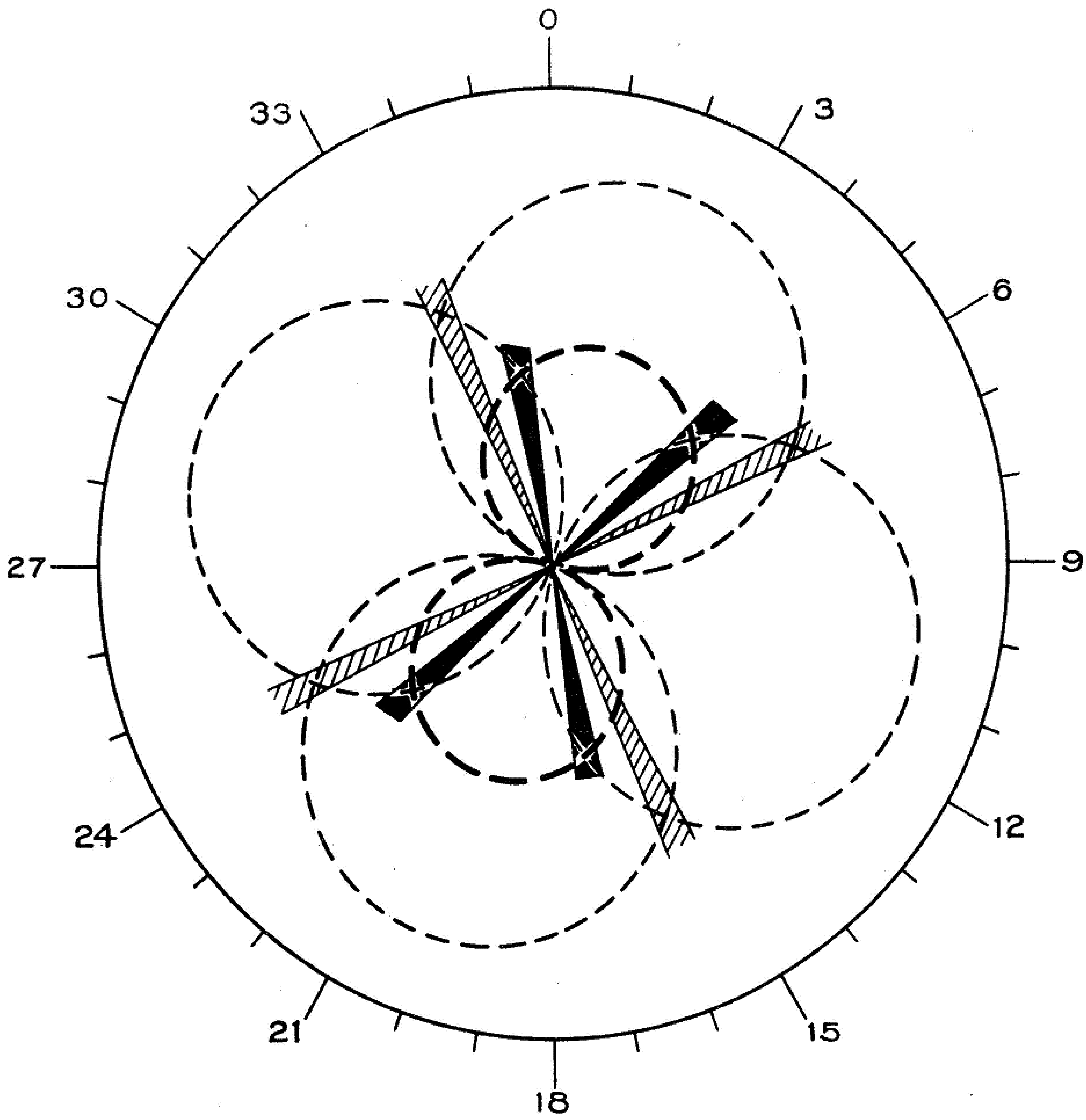

Figure 4

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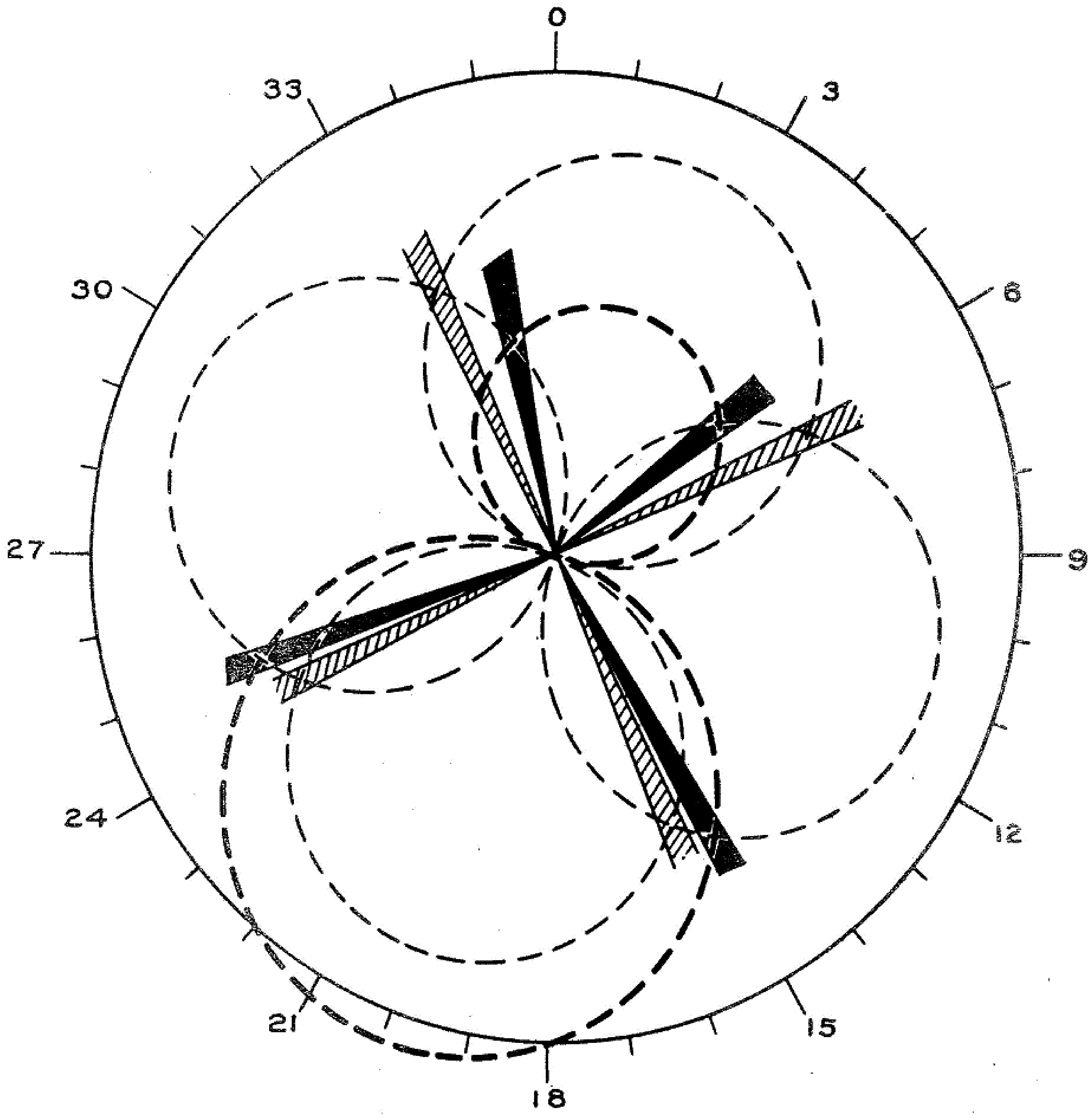

Figure 5

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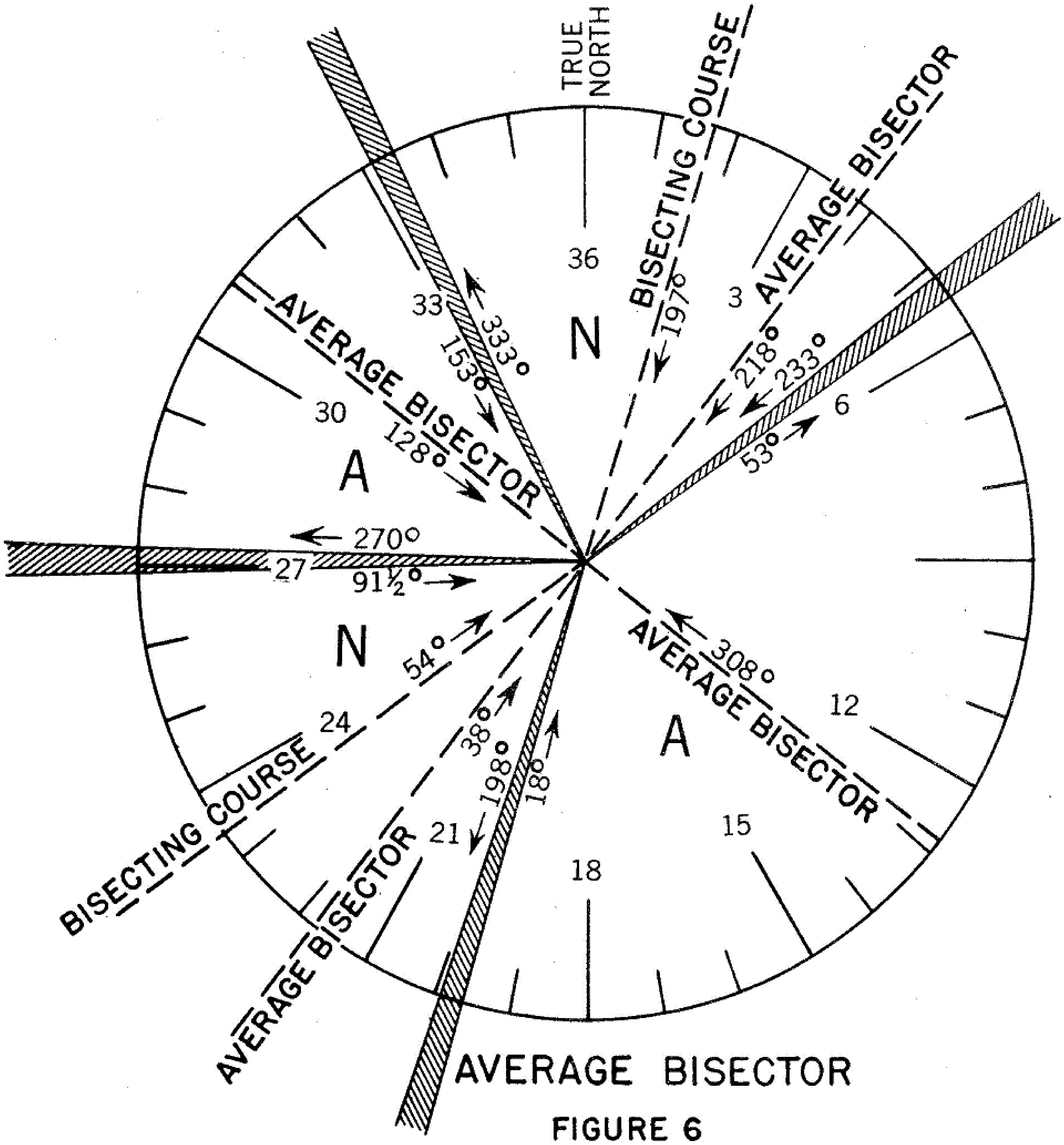
TRUE NORTH
BISECTING COURSE
AVERAGE BISECTOR
36
3
6
12
15
18
21
24
27
30
33
N
A
N
A
333°
153°
197°
218°
233°
53°
128°
270°
91½°
308°
54°
38°
198°
18°
BISECTING COURSE
AVERAGE BISECTOR
AVERAGE BISECTOR
AVERAGE BISECTOR
AVERAGE BISECTOR

FIGURE 6

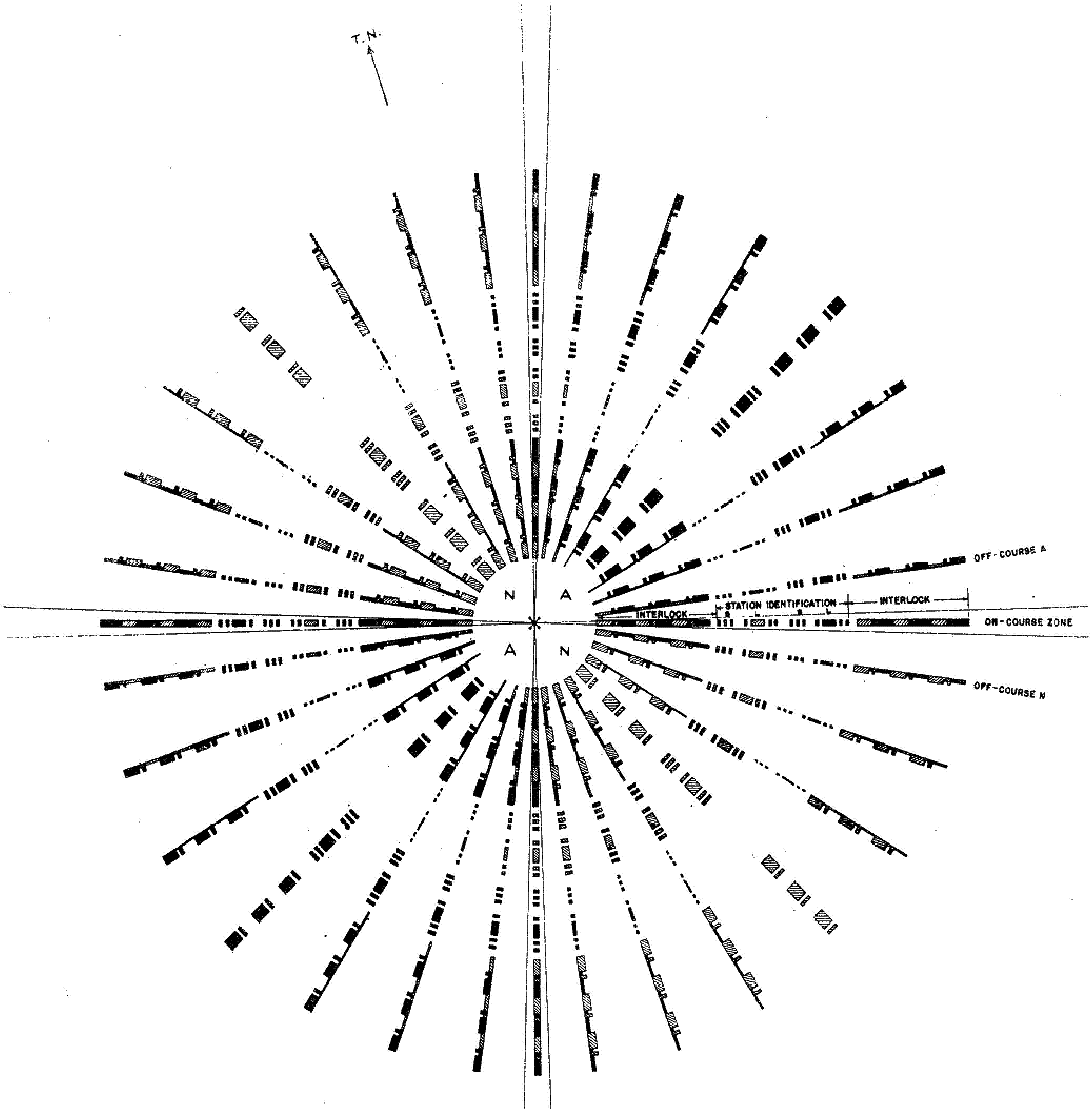

FIGURE 7

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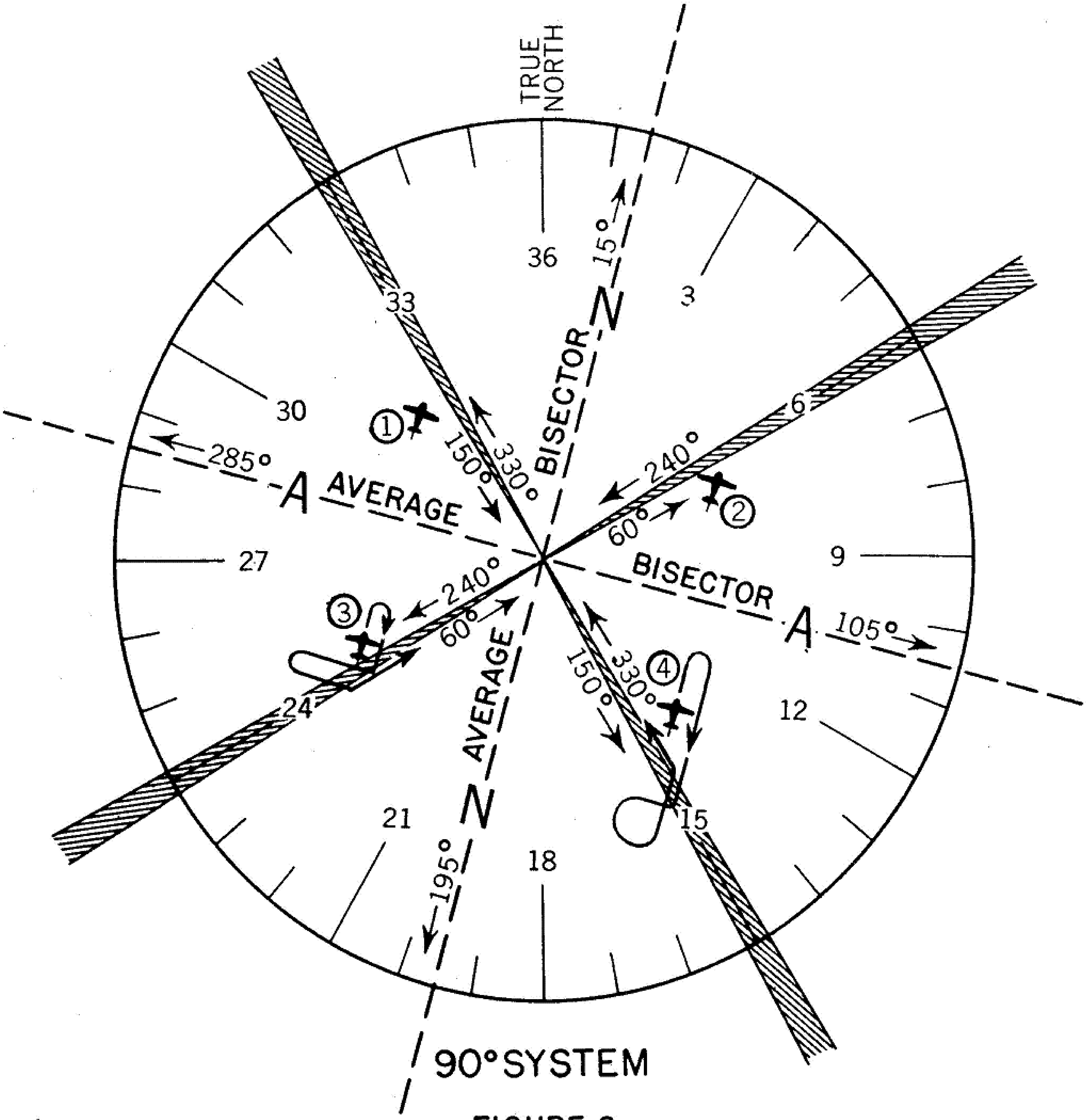

90° SYSTEM

FIGURE 8

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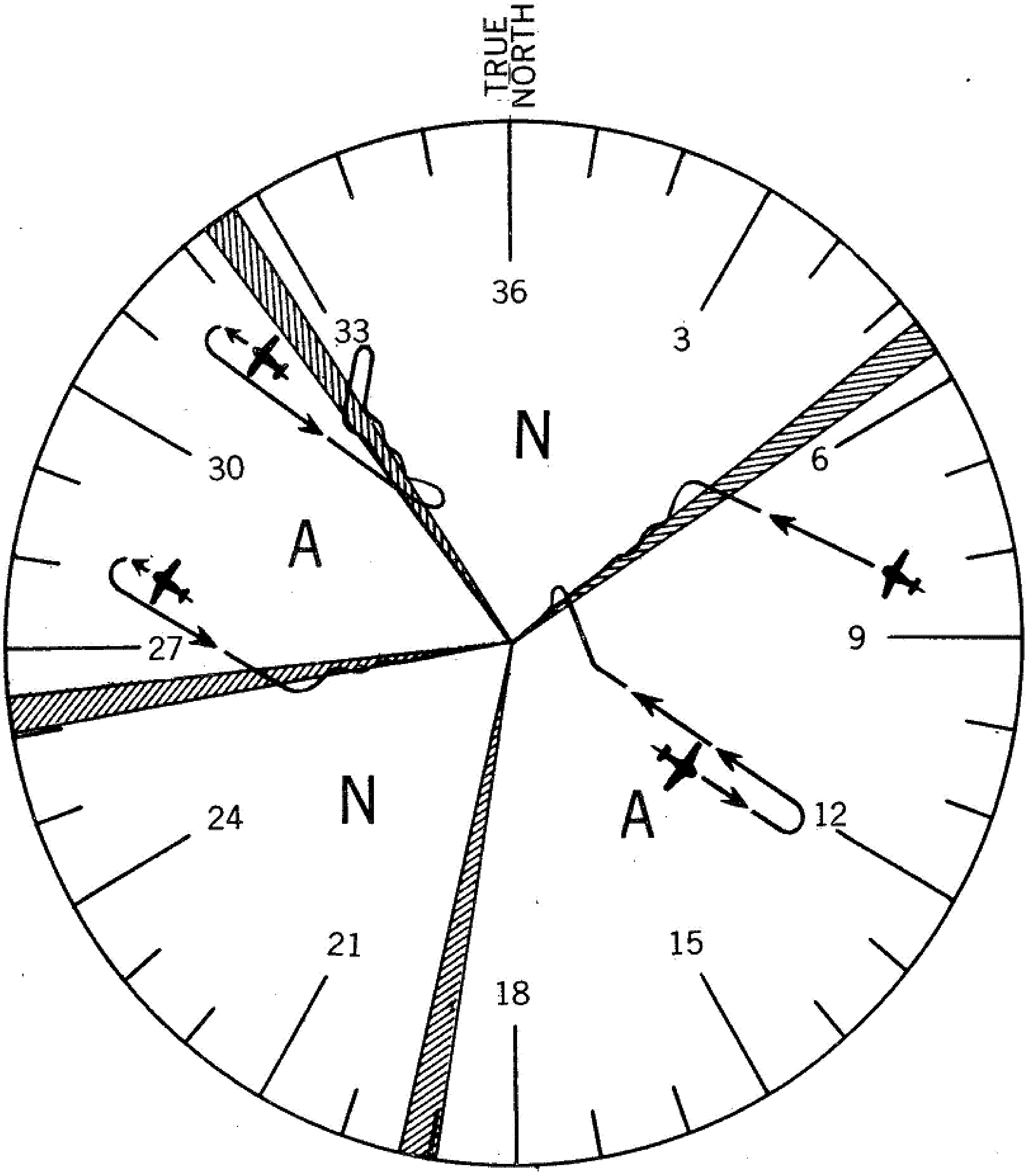

FADE-OUT SYSTEM

(FLYING PARALLEL TO AVERAGE BISECTOR)

FIGURE 9

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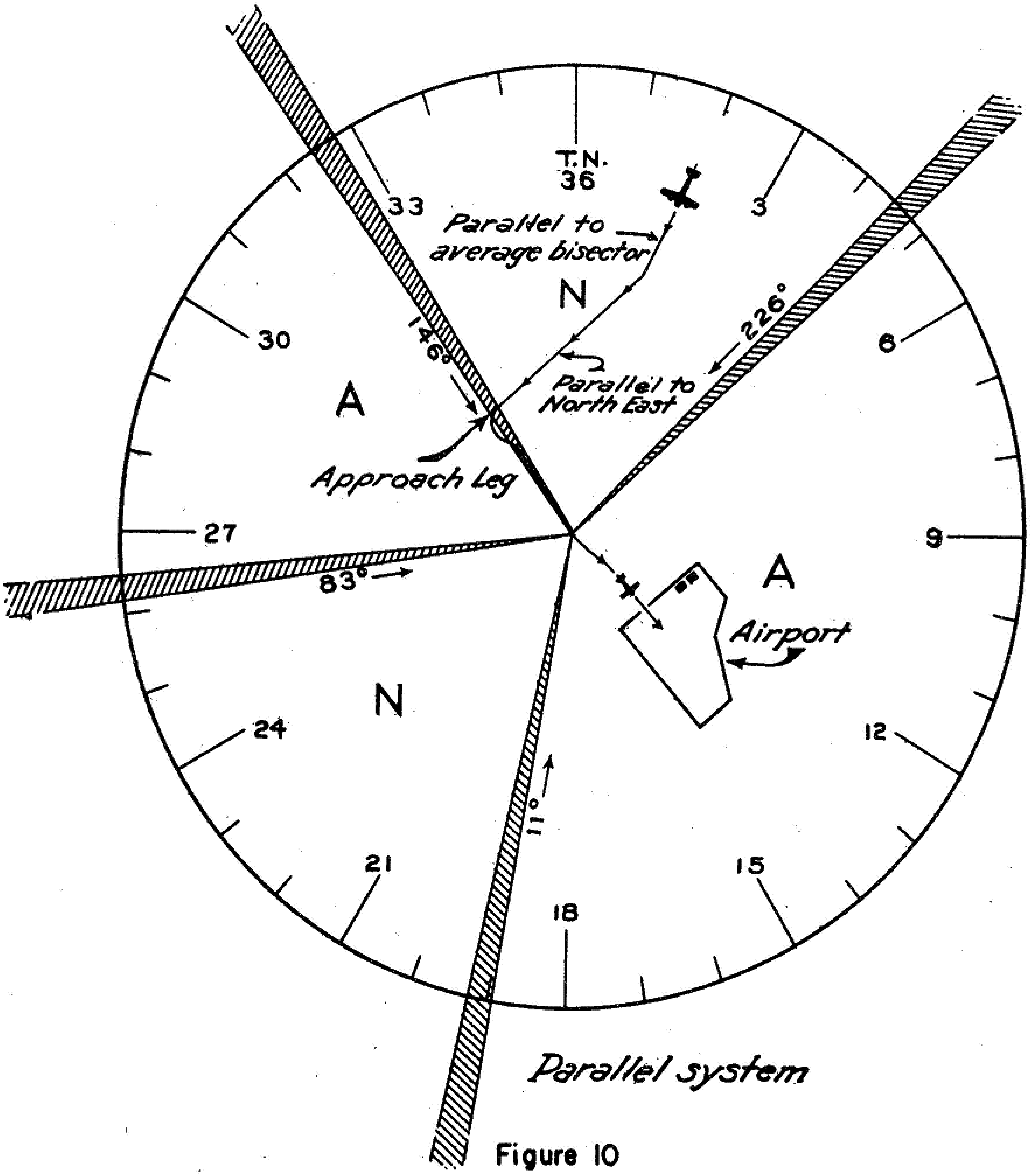
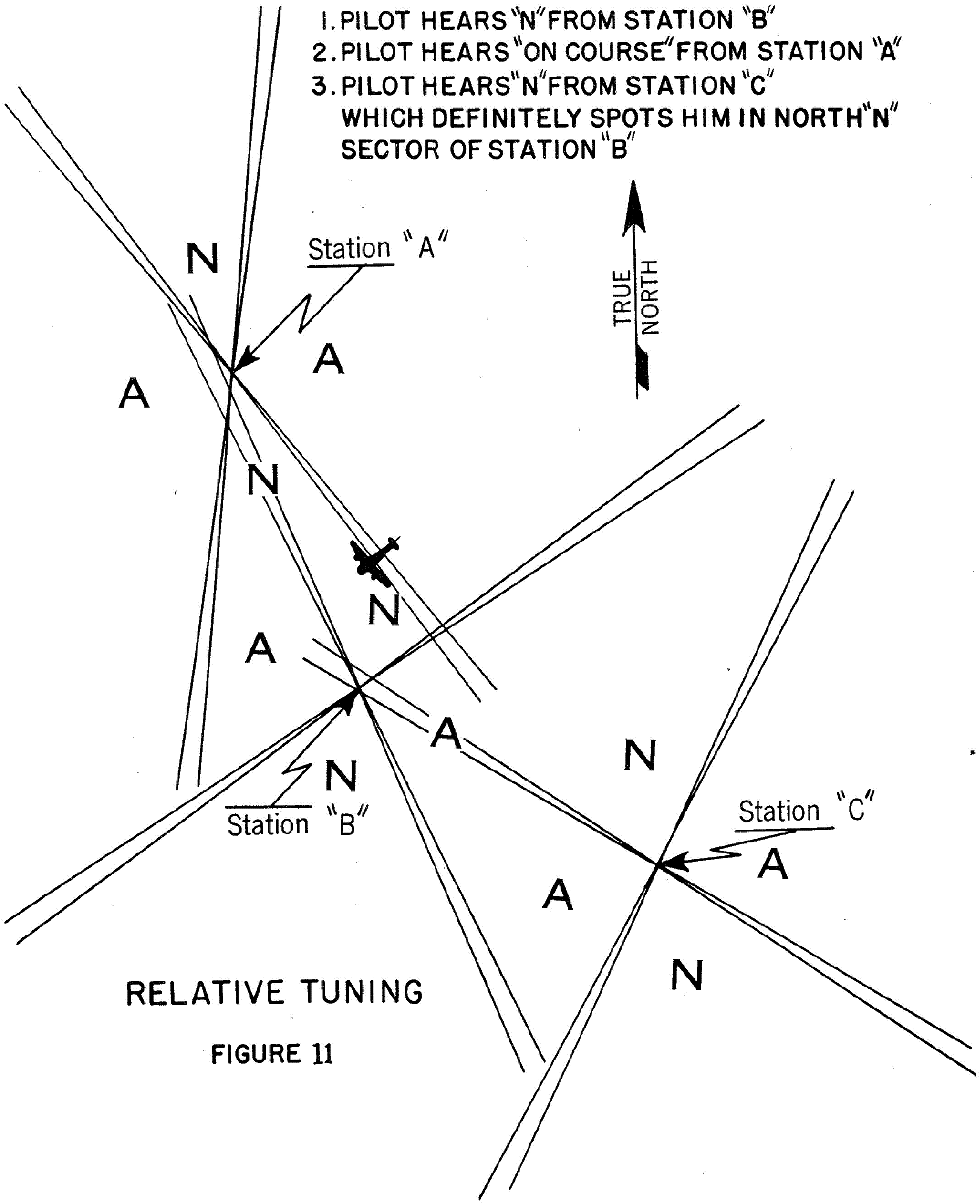

T.N.
36
3
6
9
12
15
18
21
24
27
30
33
Parallel to average bisector
N
A
226°
146°
Parallel to North East
Approach Leg
83°
A
Airport
N
11°
Parallel system

Figure 10



RELATIVE TUNING

FIGURE 11

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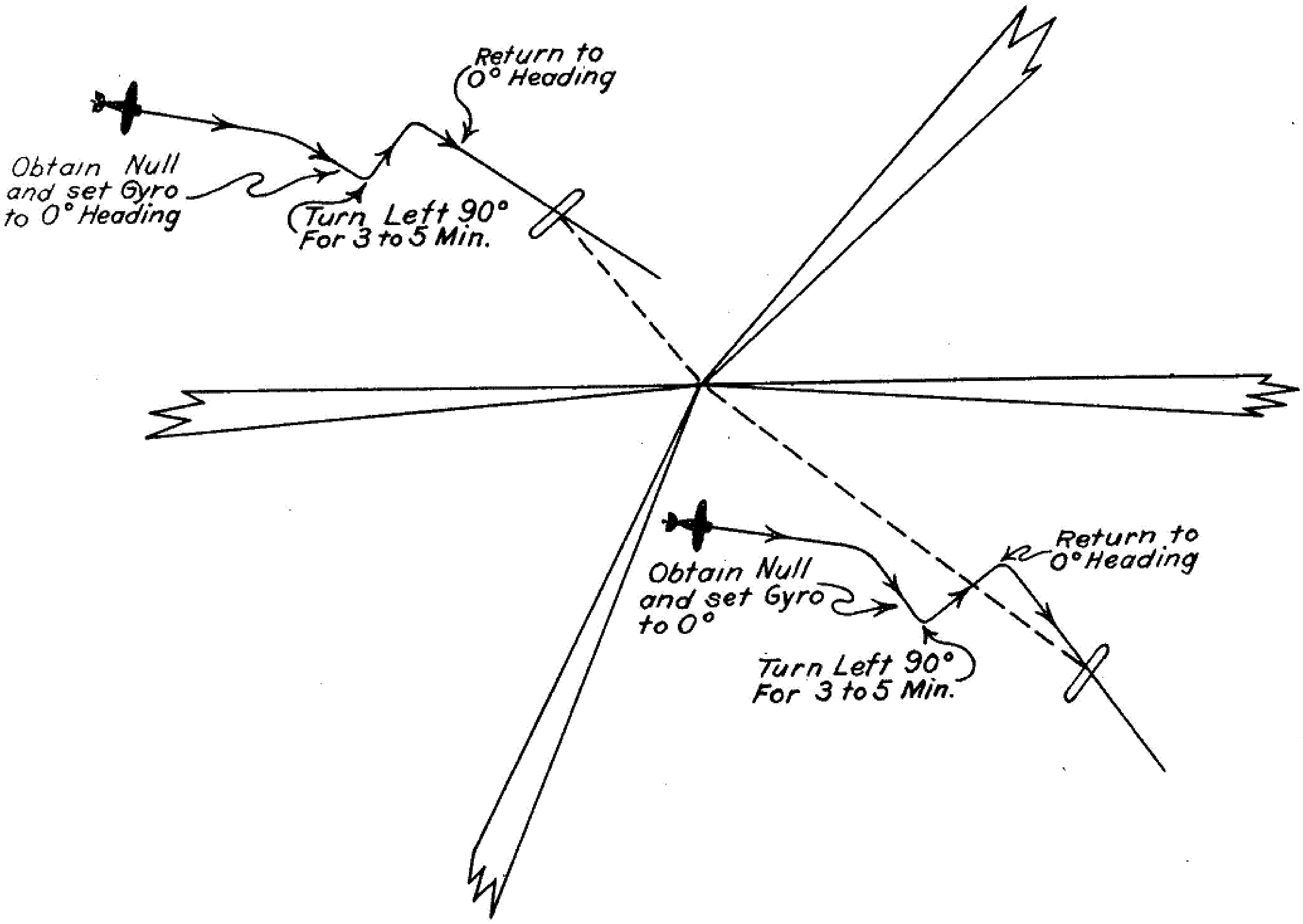
Return to
0° Heading
Obtain Null
and set Gyro
to 0° Heading
Turn Left 90°
For 3 to 5 Min.
Obtain Null
and set Gyro
to 0°
Return to
0° Heading
Turn Left 90°
For 3 to 5 Min.

Fig. 12

18660

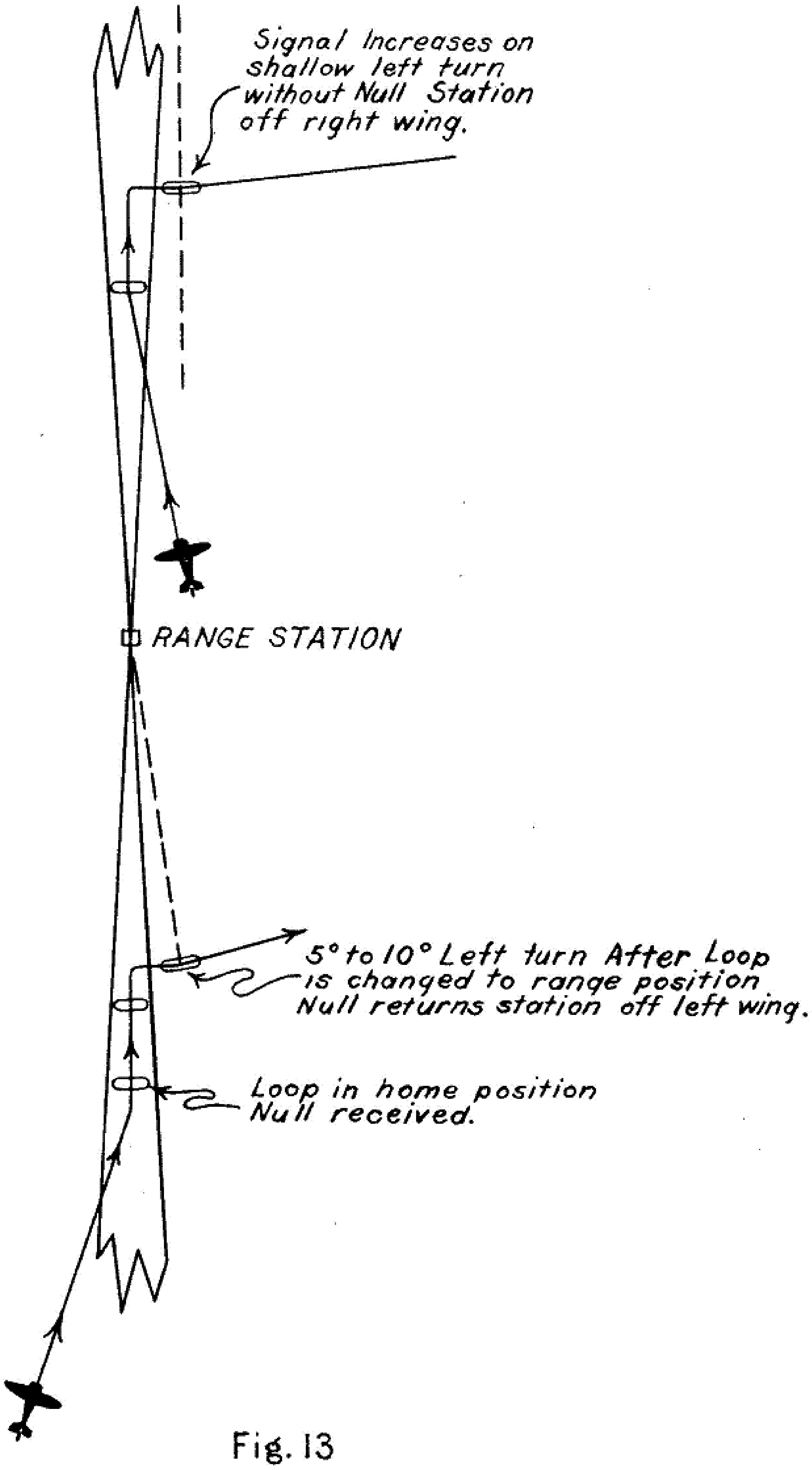
Signal Increases on shallow left turn without Null Station off right wing.
RANGE STATION
5° to 10° Left turn After Loop is changed to range position Null returns station off left wing.
Loop in home position Null received.

Fig. 13

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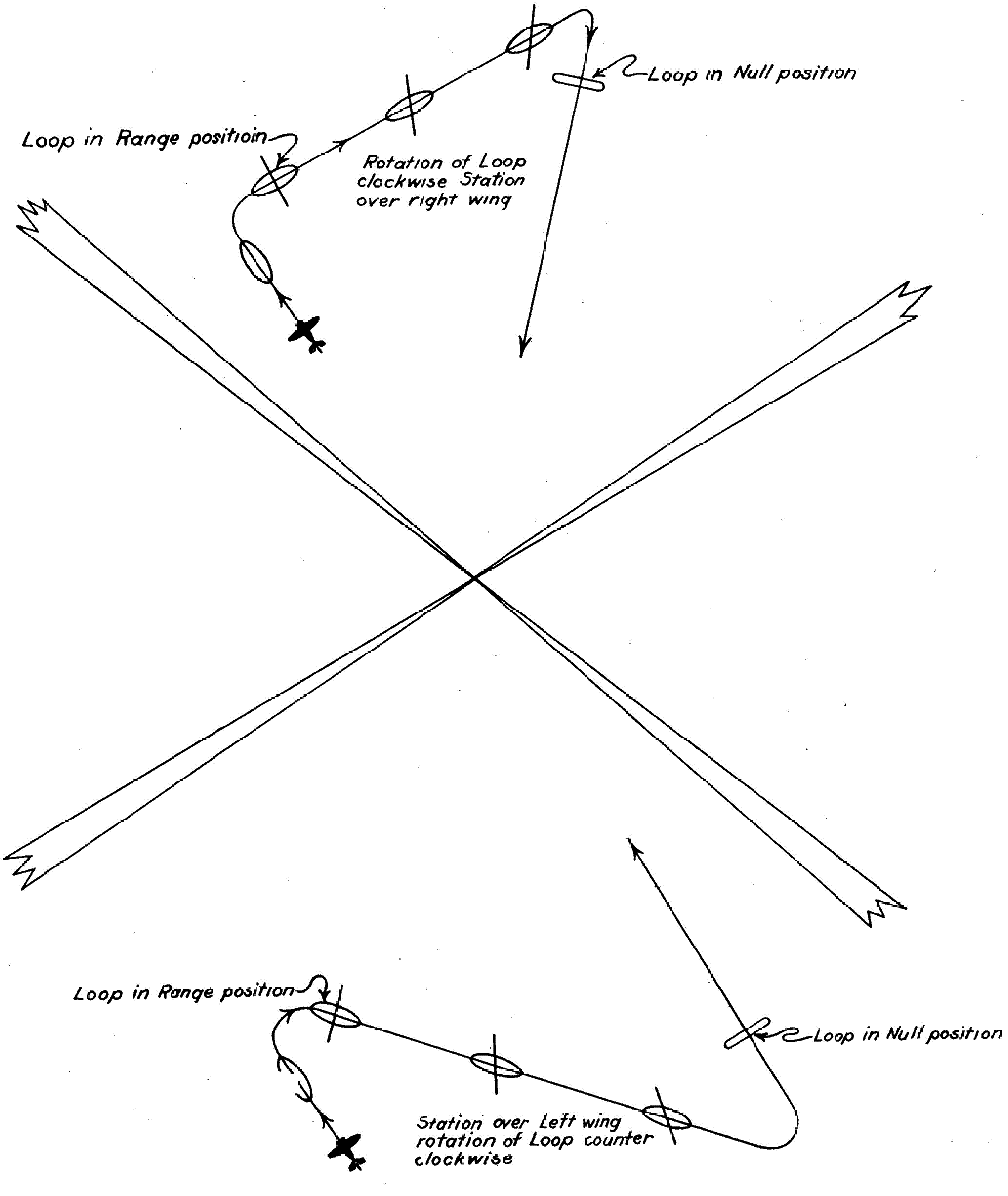

Loop in Null position
Loop in Range positioin
Rotation of Loop clockwise Station over right wing
Loop in Range position
Loop in Null position
Station over Left wing rotation of Loop counter clockwise

Fig. 14

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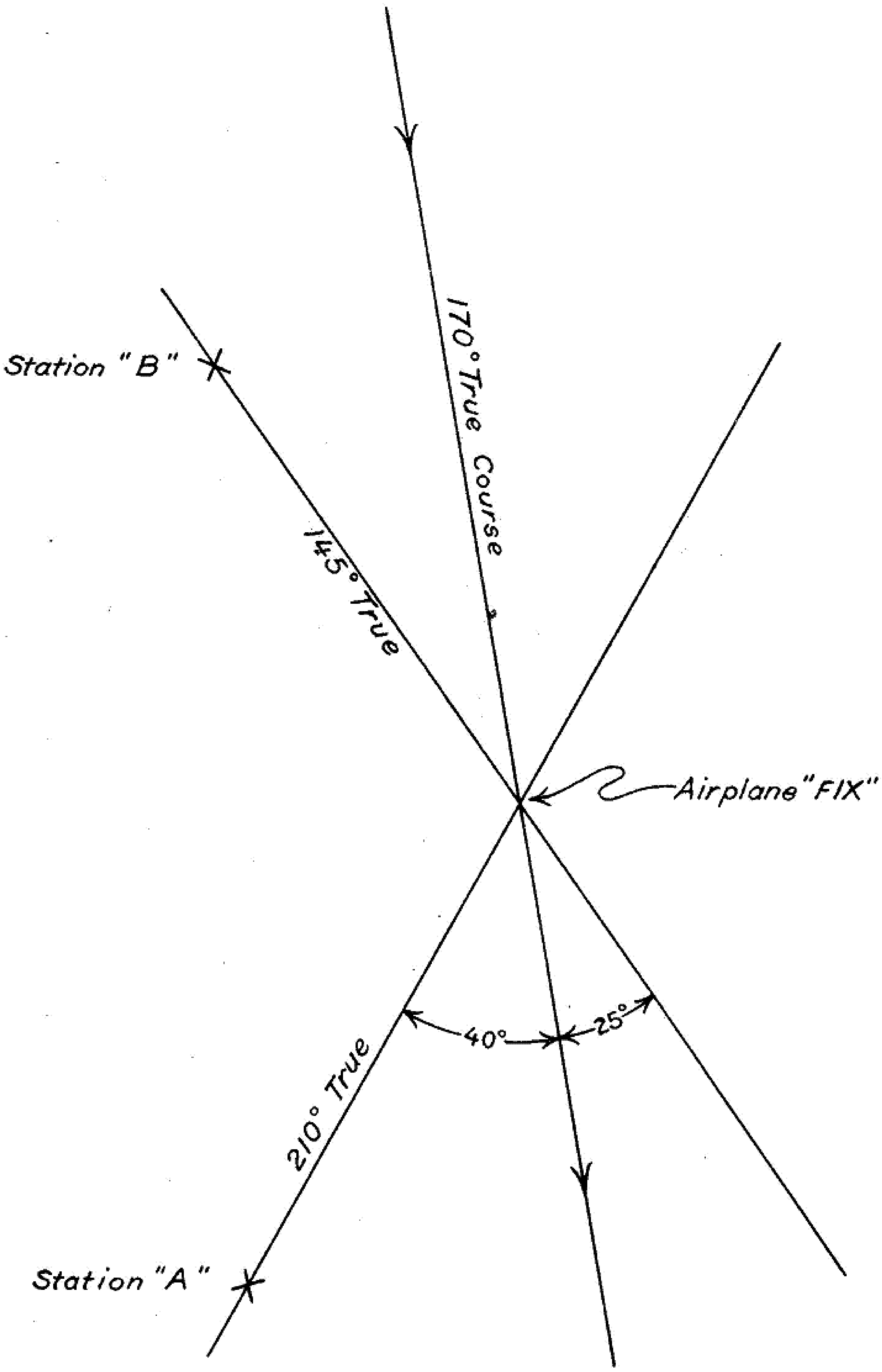

NOTE — Station "B" is actually behind the "FIX" due to ambiguity of Loop.

Fig. 15

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