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AIR PROGRESS THROUGH EDUCATION

PILOT'S DIGEST

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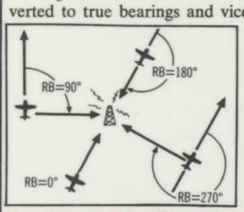
Written by: Jack Acheatel and Barry Schiff

ADF and L/MF

PD108

I. TERMS & DEFINITIONS

A. BEARINGS. **1. TRUE BEARING (TB)** is the direction of one object from another with reference to *true north*. **2. MAGNETIC BEARING (MB)** is the direction of one object from another with respect to *magnetic north*. NOTE: Magnetic bearings can be converted to true bearings and vice versa by proper application of magnetic variation.



(1) **TB = MB** $+$**Easterly** / $-$**Westerly** **Variation**

(2) **MB = TB** $-$**Easterly** / $+$**Westerly** **Variation**

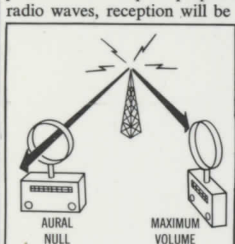
3. A RELATIVE BEARING (RB) is the bearing of an object as measured clockwise from the nose of an airplane.

II. THE AUTOMATIC DIRECTION FINDER (ADF)

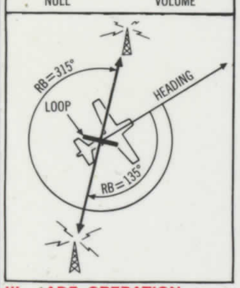
A. PURPOSE. The purpose of an ADF (frequently called a **RADIO COMPASS**) is to continually furnish the relative bearing of any suitable low or medium frequency (L/MF) station.

B. ADF RECEIVER. The ADF receiver is no more than an L/MF frequency receiver designed to receive between 190 and 1750 kc.

C. LOOP ANTENNA. The ability of the ADF to provide relative bearings is chiefly dependent on the highly direction characteristics of the **LOOP ANTENNA,** which is no more than a coil of wire wound around a rotatable loop frame. When the *plane* of the loop is parallel to or in line with the radio waves from a station, reception will be at a maximum (loud). When the plane of the loop is perpendicular or at right angles to the radio waves, reception will be at a minimum **(AURAL NULL).** The relative bearing of a station is obtained by observing the position of the loop when it has been rotated to the "null" position. The direction of the station will be in the direction of a line perpendicular to the loop. The null position is preferred for direction finding purposes because it is more sensitive and can therefore provide more accurate bearings than the "maximum" position.



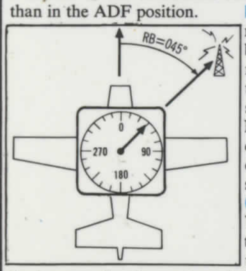
D. SENSE ANTENNA. In the illustration, the loop has been rotated to the null position. It can be seen that the station may be in either of two directions 180° apart. The inability of the loop antenna to determine which of the two possible relative bearings is correct is called the **180° AMBIGUITY** *of* the loop. A **SENSE ANTENNA** mounted on the aircraft is used to eliminate this ambiguity.



III. ADF OPERATION

A. FUNCTION SWITCH. **1.** With the function switch in the ADF position the equipment functions as an automatic direction finder, i.e., with a station properly tuned in, the loop antenna will automatically rotate to the null position and provide relative bearings. **2.** With the function switch in the RECEIVE position, the equipment will operate as *only* a standard receiver. The loop will *not* rotate and therefore will *not* provide navigational bearings. The RECEIVE position is used for tuning a station or for continuous listening, since reception is better than in the ADF position.

B. ADF INDICATOR. This is no more than an instrument calibrated from 0° to 360°. A needle rotates to provide continuous relative bearings of the station tuned on the receiver. No matter which way the aircraft is heading, the ADF needle continuously "points" to the station.

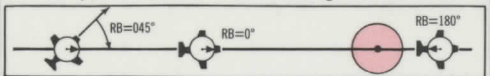


C. TEST POSITION. Engaging the **TEST BUTTON** or **TEST KNOB** causes the loop to rotate away from the null position. Rotation of the loop can be observed on the ADF indicator. Upon release, the loop will rotate back to its original position. Sluggish (or no) return to the original bearing indicates equipment failure or poor station.

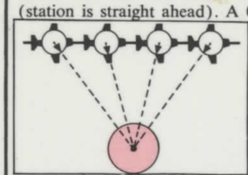
D. AUTOMATIC VOLUME CONTROL. The signal strength of any L/MF station is inversely proportional to the square of the distance between the airborne receiver and the station, i.e. the volume will continuously double as an aircraft halves its distance from the station and vice versa. To alleviate the chore of having to continually adjust the **MANUAL VOLUME CONTROL (MVC),** many L/MF receivers incorporate an **AUTOMATIC VOLUME CONTROL (AVC)** which automatically maintains a constant volume, similar to a standard broadcast receiver.

IV. HOMING TO A STATION

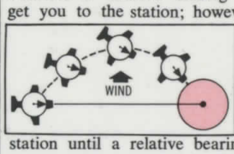
A. HOMING WITHOUT A CROSSWIND. After the station has been properly tuned in and *identified,* the pilot notes the relative bearing of the station; in this case, 45° to the right of the nose. A right turn of 45° is made. As the aircraft turns toward the station, the ADF needle, always pointing toward the station, will slowly rotate toward a relative bearing of 0°. At the completion of the turn, the aircraft will be pointing toward the station and the ADF needle will show a relative bearing of 0° (station is straight ahead).

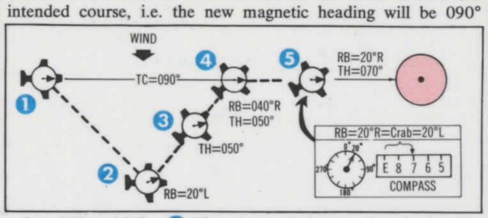


A 0° relative bearing is *maintained* by making slight corrections as necessary toward the needle. As the station is approached, the needle will vary either side of 0° and then swing abruptly to a reading of 180° to indicate the station has been passed. If a 0° relative bearing is not maintained and the aircraft passes the station off to one side, the needle will rotate more slowly, always pointing toward the station.



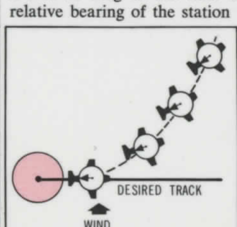
B. HOMING WITH A CROSSWIND. Homing toward a station with a constant 0° relative bearing under crosswind conditions will get you to the station; however, the path of flight will be a curved route. In a strong crosswind, this curved flight path may be very pronounced. The procedure used to maintain a direct route to a station is as follows: **1** Turn toward the station until a relative bearing of 0° is indicated; then note the magnetic heading, in this case 090°. **2** As the aircraft drifts off course (*still maintaining a heading of 090°*), the relative bearing will change. To determine the direction of drift, use the following rule: **IF THE ADF NEEDLE MOVES LEFT, DRIFT IS RIGHT: IF THE NEEDLE MOVES RIGHT, DRIFT IS LEFT.** In this case, the needle deflected to the left, indicating a relative bearing of 340°. The 20° **BEARING ERROR** represents a right drift (needle moved 20° left). **3** To return to course, a turn equal to twice the BEARING ERROR should be made toward the intended course, i.e. the new magnetic heading will be 090° − 2 × 20° = 050°. **4** The pilot will know when he has intercepted the original course when the relative bearing equals the difference between the magnetic heading of the aircraft (050°) and the direction of the intended course (090°), in this case 040°. **5** The desired course will be maintained as long as the pilot crabs into the wind an amount equal to the *original* bearing error of 020° (i.e. a magnetic heading of 070°). The relative bearing will be equal to the crab angle of 20°. *The pilot will always know that he is still on course as long as the amount of crab being used is equal to the relative bearing.* If the wind should change, an off course drift would be detected when the amount of crab does not equal the relative bearing. In such an event, steps 1-5 should be repeated.





V. FLYING FROM A STATION

The procedures used in homing *away* from a station are identical to the procedures used in homing toward a station under crosswind conditions. The relative bearing will be approximately 180° (station behind the aircraft) rather than 0° as used in homing *toward* a station. The aircraft will be on course as long as the crab angle being used is equal to the relative bearing of the station *"off the tail."* Although a curved path can be flown *toward* a station while maintaining a constant 0° relative bearing, it is almost impossible to fly away from a station and reach a given destination without *crosswind correction.* With even the slightest crosswind, the aircraft will be led farther and farther from the intended course as long as a constant relative bearing of 180° is maintained.

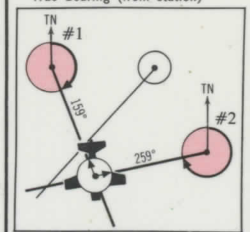


VI. ESTABLISHING ADF FIXES

An ADF fix is only obtainable when **(1)** the aircraft is directly over a station or **(2)** when true or magnetic bearings are established *from* two or more different stations, the intersection of which establishes a definite fix. To obtain a true bearing from the aircraft to the station, the relative bearing must be added to the true heading. If the sum is greater than 360°, subtract 360° to obtain a figure between 0° and 360°. Since the position of the aircraft is allegedly unknown, the *reciprocal* of the true bearing is required so that the bearing may be plotted *from* the station *to* the aircraft.

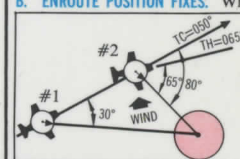
A. TRIANGULATION. A pilot tunes in, identifies, and takes relative bearings on each of two stations.

	Station #1	Station #2
Relative Bearing	171°	273°
True Heading	+166°	+166°
True Bearing (to station)	337°	439°
(−360°)	—	−360°
True Bearing (to station)	337°	79°
(±180°)	−180°	+180°
True Bearing (from station)	157°	259°



The obtained true bearings of 157° and 259° are then plotted from stations #1 and #2 respectively to obtain a fix. HINT: **(1)** To obtain maximum accuracy, the relative bearings should be taken in rapid succession. **(2)** Be sure the headings used in the computations are the actual headings of the aircraft at the instant the relative bearings are noted. **(3)** If bearings are taken on three stations, as in the illustration, the true bearings from the station will probably form a small triangle, the center of which is the "fixed" position of the aircraft. **(4)** The most accurate fixes are made when the stations selected provide bearings which cross at relatively large angles.

B. ENROUTE POSITION FIXES. When flying enroute along a *known* course, it is relatively simple to determine the position of an aircraft along that course by determining the relative bearing of a station off to one side. Aircraft #1 is maintaining a TC of 050° under no-wind conditions and obtains a relative bearing of 030° to the station. The pilot, by referring to his chart, can *visualize* where he would have to be along his course to get a relative bearing of 030° to the station; or he could merely draw a line from the station to the course in such a manner that the line from the station approached the course line at a 030° angle. Since aircraft #2 is crabbing 15° into the wind, the pilot will have to add (or subtract) the crab angle to the relative bearing to obtain a fix. E.g.: The pilot obtains a relative bearing of 065° and adds 15° (crab angle) to obtain 80°, which is the angle of the station from the course line.



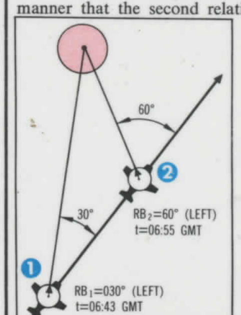
VII. TIME AND DISTANCE TO THE STATION

A. METHOD I — WING TIP BEARINGS. Turn the aircraft until the relative bearing of a station is 90° or 270°. The station will be located *off the wing tip.* Note the time and hold a constant heading until the relative bearing changes at least 5° but not more than 20°. In any case, fly at least one minute. Use the time and bearing change in the following formulas:

$$\text{MINUTES TO STATION} = \frac{\text{MINUTES FLOWN BETWEEN BEARINGS} \times 60}{\text{DEGREES OF BEARING CHANGE}}$$

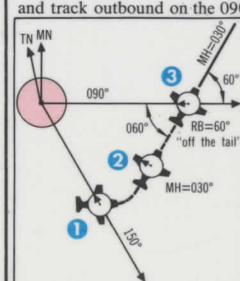
$$\text{MILES TO STATION} = \frac{\text{MINUTES FLOWN BETWEEN BEARINGS} \times \text{EST. GS}}{\text{DEGREES OF BEARING CHANGE}}$$

B. METHOD II — DOUBLING THE ANGLE. Two relative bearings are obtained on a station in such a manner that the second relative bearing is exactly double the first relative bearing. In this way, an isosceles triangle is formed and the distance flown between bearings is equal to the distance to the station at the time of the second bearing. The time checks are usually taken for even relative bearings such as 25°-50°, 30°-60°, 45°-90°, etc. Constant course and groundspeed must be maintained between readings. If the time between positions **1** and **2** was 12ᵐ, then the estimated time enroute from position **2** to the station is also 12ᵐ.



VIII. INTERCEPTING AN ADF RADIAL

An **ADF RADIAL** is the *magnetic direction* of any of 360 courses emanating at and leading from an L/MF station. Should a pilot find it necessary to intercept a given radial, the following steps should be followed. Assume that a pilot wishes to intercept and track outbound on the 090° radial of a station. **1** Locate the aircraft relative to the course to be intercepted, either by reference to the ground or as being on a specific magnetic course or radial (bearing) from the station. **2** Turn in the direction required to intercept the desired radial. In the illustration, the pilot has taken up a heading so as to intercept the radial at a 60° angle. MC − MH = 090° − 030° = 060°. **3** By inspection it is easy to see that when the aircraft intercepts the desired course, the ADF needle



will be 60° to the left of the tail, i.e. the relative bearing "off the tail" will be equal to the angle of intercept, 060°. If the magnetic heading were selected so as to cause an inbound intercept, the relative bearing would, of course, be measured "off the nose." **(4)** Once the course has been intercepted, a turn is made to either an inbound or outbound heading of 270° or 090°.

IX. ADF ERRORS

The ADF points in the direction from which signals are being received. It therefore follows that if the signal is *apparently* coming from a direction other than from the transmitting station, the ADF will provide an erroneous bearing.

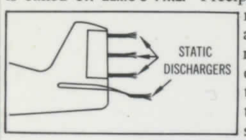
A. NIGHT EFFECT. At night, the descending ionosphere produces **SKY WAVES** which are reflected radio waves and are useless for ADF navigation. These conditions are particularly pronounced during the twilight hours. Sky waves, however, greatly increase the *reception distance* of an L/MF station. At night, navigate only by the strongest signals received from nearby stations which are at the lowest frequencies possible. *Never* use a station that gives erratic directional indications.

B. TERRAIN EFFECT. Mountains have the ability of reflecting radio waves. When flying near mountains, use only strong stations that give definite directional indications.

C. COASTLINE EFFECT. Coastlines have the ability to **REFRACT** radio waves. When flying near a coastline, use no station for ADF navigation from which the signal received will cross over the shoreline to the aircraft at an angle of less than 45°.

D. ELECTRICAL STORMS. When in close proximity to severe electrical storms (thunderstorms) the ADF needle may point to the center of the storm rather than the station being used. The erratic behaviour of the needle may make the ADF equipment useless. DO NOT UNSUSPECTINGLY FOLLOW THE NEEDLE TO A THUNDERSTORM.

E. PRECIPITATION STATIC. At the frequencies which enable an ADF to operate, **PRECIPITATION STATIC** caused by rain, snow, or cloud droplets may be so severe as to cause the ADF needle to wander aimlessly. Reception may be so hampered that it will be impossible to identify a station. Precipitation static is the result of an accumulation of static charges on various portions of the airplane such as the wings, tail, and propellers. When these charges become great enough, they will discharge into the surrounding air. This *static discharge* can sometimes be seen as "dancing lights" on the exterior of the aircraft and is called **ST. ELMO'S FIRE.** Precipitation static can sometimes be reduced by the reduction of airspeed. **STATIC DISCHARGERS** may be used to promote the quiet discharge of static electricity and are installed at the trailing edges of the control surfaces.



X. L/MF STATIONS

In general, the maximum distance at which an L/MF station can be received is chiefly dependent upon the power (in watts) of the station transmitter. E.g.: A 100 watt station can be received at a greater distance than a 50 watt station. At night, however, sky waves (discussed earlier) can increase the reception distance of a given station many times.

A. NON-DIRECTIONAL RADIOBEACONS (RBN). These stations, quite often referred to as **HOMING BEACONS** or **HOMERS**, are stations intended for use with an ADF and serve no other navigational purpose. They are identified by a three letter code group.

DESIGNATION	POWER
MH	Less than 50 watts
H	50 to less than 2000 watts
HH	Over 2000 watts

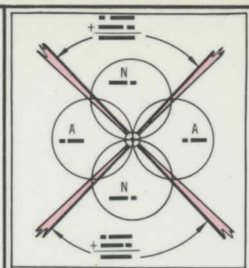
B. COMMERCIAL BROADCAST STATIONS. These stations are ideally suited for homing since many of them transmit with as much as 50,000 watts (maximum in U.S.A.). Two drawbacks are **(1)** the stations identify themselves infrequently, and **(2)** many of them have limited hours of operation.

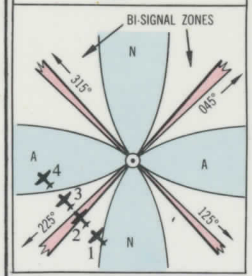
C. L/MF RADIO RANGES. Although these stations can be used for purposes other than homing (discussed later), they can be used in a manner identical to that of any other L/MF station used for homing. These **"LOW FREQUENCY RANGES"** are divided into two distinct categories depending on the type of transmitting antenna being utilized. The most predominant and modern of these stations utilize **ADCOCK ANTENNAS,** whereas the older stations utilize **LOOP ANTENNAS.** The advantages of the Adcock range over the loop range are (1) night effect is reduced to a minimum on Adcock ranges, and (2) the loop range is not suitable for ADF navigation. L/MF ranges are relatively low powered and are therefore limited to short-range navigation.

ADCOCK	LOOP	POWER	RANGE
MA	ML	Less than 50 watts	25 miles
MRA	MRL	50 to less than 150 watts	50 miles
RA	RL	150 watts or more	100 miles

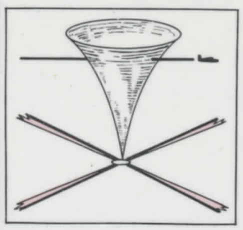
XI. THE L/MF RADIO RANGE

A. SIGNAL PATTERN. The **L/MF RADIO RANGE** consists of two pairs of antennas, each of which transmits a signal pattern in the form of a "figure 8" at approximately right angles to each other. One pair of antennas continuously transmits the code letter **N** (—.) and the other pair of antennas transmits the code letter **A** (.—). In the areas where the four "clover leaves" overlap, the .— and —. combine to form **COURSES** or **BEAMS** or **LEGS.** The areas between the legs are alternately called the **N** and **A QUADRANTS.** When tuned to the station, an aircraft located in any of the quadrants will hear the respective Morse code letter being continuously transmitted. Due to the "interlocking" of the A and the N, only a continuous tone is heard when a pilot is "on the beam." Radio range legs are 3° wide, i.e. the width of a leg increases 3 miles every 60 miles from the station; very close to the station, they are the width of the landing gear. Approximately 30° either side of any leg is an area where not only will the N or the A be heard but a background tone will also be heard, indicating that the aircraft is near a leg. This area is called the **BI-SIGNAL ZONE.** As a leg is approached from within a bi-signal zone (position #1), the background tone will become progressively more predominant until finally, when the leg is reached (position #2), the N signal will no longer be heard and only the steady "on-course" tone will be heard. After crossing the leg, the aircraft will enter the A bi-signal zone (position #3), at which time the A signal will be heard and the steady on-course signal will gradually fade. When the steady tone is no longer heard (position #4), the aircraft will be in a **CLEAR A QUADRANT** and only a continuous transmission of pure A's will be heard. Although N and A quadrants are not identified by letter on aero charts, they can be identified by one of two methods: **(1)** Visualize or draw a line from the station to *true* north. The quadrant containing this line is an N quadrant followed clockwise by the A quadrant, N quadrant, and A quadrant respectively. Should one of the legs coincide with the true north line, the northwest quadrant will be the N quadrant. Note: In Canada the N quadrant is located using a 315° true bearing from the station. **(2)** Notice that each of the four legs is bordered on one side by a dark line. The dark lines serve to enclose the N quadrants. The legs are numbered clockwise from true north. If a leg coincides with true north, that would be the #1 leg. Legs are also referred to as the "northeast leg," etc. The directions of all legs are given as magnetic courses.





B. THE CONE OF SILENCE. Immediately above the range station, the antenna signals cancel each other out and *no signal can be heard.* This area has the shape of an inverted cone (diameter increases with altitude above the station).



C. STATION SHAPES. (1) SQUARE RANGE: The legs form a perfect cross. **(2) SCISSORS RANGE:** The legs take the form of a "scissor like" pattern. **(3) CROWFOOT RANGE:** A range other than a square or scissors range.

D. FLYING THE BEAM. It should be apparent that flying a range leg is dependent upon the pilot's ability to interpret the aural signals of the range. *When flying the range, the AVC must be "off."* As long as a steady monotone is heard, the aircraft is on a leg. An off-course drift is detected by the presence of an A or an N signal. Appropriate heading changes would then be made with reference to the chart. As the station is approached, the wedge-shaped beam becomes progressively narrower and staying on course becomes more difficult. The volume will gradually increase while tracking inbound. Near the station, the volume builds quite rapidly and manual adjustment of the volume control will be necessary to maintain a comfortable level. Upon encountering the cone of silence, the signals will rapidly fade out. Upon departing the cone, the volume will swell back, and as the aircraft proceeds away from the station the volume will gradually decrease. Another definite indication of station passage is the reversal of signals. E.g.: If the N quadrant was on the pilot's left while flying inbound, it will then be to the right of the leg when flying outbound on the other side of the station.

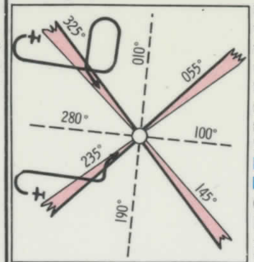
E. STATION IDENTIFICATION. Every 30 seconds, all range signals are stopped while the three letter Morse Code identification is being transmitted. The identification is transmitted twice, *first* to the N quadrants and *then* to the A quadrants. In the clear N quadrants, only one station identification will be heard *followed* by a pause. In the clear A quadrants, the identification will be *preceded* by a pause. On the range legs, both station identifications are heard with equal intensity. In the bi-signal zones, two sets of identification signals with unequal intensity will be heard and their relative loudness will aid in anticipating the nearness of the on-course leg.

F. RANGE IRREGULARITIES. (1) At night, more than 30 miles from a station, **SWINGING, MULTIPLE** or **BENT BEAMS** may be encountered. These irregularities are most common with the loop type range. **(2)** Large mountains tend to reflect and mineral deposits tend to attract L/MF radio waves, sometimes causing **BENT BEAMS. (3)** Beams crossing a shoreline at other than a 90° angle are refracted. **(4) FALSE CONES** are sometimes encountered over depressions in the earth such as canyons, quarries, etc., and cause momentary fades in volume. **(5)** On crow-foot ranges, a **CANTED** or **TILTED CONE** may be expected at high altitudes. **(6)** Some ranges have an automatic monitoring device which will automatically transmit a group of three U's (. . —/. . —/. . —) between station identification transmissions whenever irregularities exist at the station.

XII. L/MF RADIO RANGE ORIENTATION.

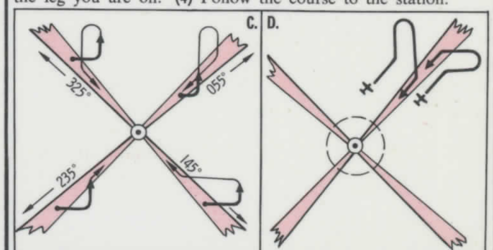
The term **RANGE ORIENTATION** applies to procedures used in getting to an L/MF range from an unknown position when the aircraft is equipped with only an L/MF receiver (no ADF).

A. AVERAGE BISECTORS are lines that cross at right angles to each other and approximately bisect each of the 4 quadrants of a range station. The directions of the average bisectors are obtained by adding the directions of the four legs of a station and dividing by 4. The station in the illustration has leg directions 055°, 145°, 235°, and 325° which when added = 760°, which when divided by 4 produces one of the average bisectors, 190°. The other three bisectors are obtained by progressively adding (or subtracting) 90° to the computed bisector.



B. TRUE FADE 90° ORIENTATION METHOD. (1) Identify the station. **(2)** Turn to the nearest bisector heading of the identified quadrant. Assume an A is heard. The aircraft could be in either of two quadrants. **(3)** If a definite fade in volume is heard, the aircraft is heading away from the station; a build would indicate flight toward the station. This identifies the quadrant. In this case, a fade was heard and the pilot reversed course to 100°. The identification quadrant should be verified by a build in volume. **(4)** Upon intercepting *and passing through* a leg, an immediate 90° left turn is made. If the beam is re-entered within one minute, the southwest course was intercepted. If the beam is not re-entered within one minute, the northwest course was intercepted. **(5)** Follow the intercepted course to the station.

C. ON-COURSE ORIENTATION. This procedure is used if, upon tuning a station, an on-course signal is heard. **(1)** Turn immediately to any bisector heading (preferably the one requiring the least heading change). **(2)** When the first off-course signal is heard (either an A or an N), two courses of this range are eliminated. **(3)** A 90° turn to the left will immediately identify the leg you are on. **(4)** Follow the course to the station.



D. CLOSE-IN PROCEDURE. If, while executing either of the aforementioned procedures, rapid changes in range signals are heard and the signal strength of the station is strong, the aircraft is located close-in to the station. **(1)** Assume the outbound heading of any leg. **(2)** Maintain this heading until a definite fade in volume is encountered. **(3)** The aircraft will be located adjacent to or on the leg used for determining the outbound heading. **(4)** By reference to the range signals being heard, execute a procedure turn, intercept the leg, and track inbound to the station.

XIII. MARKER BEACONS

MARKER BEACONS (also called **LOCATION MARKERS** or **FAN MARKERS**) are strategically located along radio range legs and airways and serve to fix the position of an aircraft along a specific course. *All* fan markers transmit on 75 megacycles and require the use of an airborne marker beacon receiver. When approximately *over* the marker, the continuous identification of the marker will be heard and the position of the aircraft will be fixed. The fan markers **(FM)** commonly in use along the airway system are either *elliptically* shaped or *bone* shaped (sometimes called a **BONE MARKER**). They usually have a power output of 100 watts and are effective up to 20,000′. Occasionally a low powered fan marker **(LFM)** with a 5 watt power output may be installed close in to a station. The LFM appears on aero charts as a relatively small ellipse. The bone marker, as illustrated, is "pinched in" where it crosses the enroute course so as to provide a more accurate fix. The transmission area of a fan marker increases somewhat with altitude. The illustration shows the dimensions of the signal reception area at 3,000′. At 10,000′ above the station, the pattern widens to 12 miles and is about 35 miles in length. Fan markers are continuously identified by means of a 3,000 cycle coded signal. In addition, many marker beacon receivers incorporate a white light that will flash the identification when flying over the marker. When associated with the four-legged range, the markers will identify themselves in relation to the range leg they are located on and the number of markers on that leg. E.g.: The second marker out on the #3 leg would be identified by 2 dots (second marker) and 3 dashes (third leg). Note: In general, the first marker on a leg will not use any dots in its identification. Most L/MF ranges incorporate a **Z MARKER** (designation = Z) which is used to positively identify station passage of an L/MF range. Since the Z marker is transmitted up through the cone of silence, it can only be received when approximately over the station. It can be identified by its continuous high pitched (3000 cycle) squeal or continuous lighting of the marker beacon light.