

RESTRICTED

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OBSERVER



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The RCAF OBSERVER

Incorporating the RCAF Navigation Bulletin

Founded 1949

The past few years have seen the RCAF OBSERVER adopt a policy of publishing articles on modern equipments and technical developments in the Observer field. What is the purpose of these articles, and what is the reader's reaction to them? To date, the reaction has been one of silence, whether it be a satisfied or indifferent silence we do not know.

Why has the OBSERVER embarked on a policy of presenting articles mainly of a semi-technical nature? The answer is that in our opinion the role of this publication is to ensure that the air observer is kept up-to-date in every aspect of the three fields associated with his trade. Unfortunately, once the observer has completed a post-graduate course, he seldom has an opportunity to be informed of current technical and operational developments not directly connected with his particular job. It is our object to provide primarily for this type of reader, while always keeping in mind the "general-interest" reader.

In general, there have been few articles on the operational aspects of the observer's tasks in the RCAF. To be of maximum value, these articles must come from the reader in the operational commands; it is our hope that this will be a feature of future issues.

This issue includes an article outlining the principles of inertial navigation which we hope will be widely read. Inertial navigation is developing rapidly, and it is essential that observers in the RCAF understand the fundamentals of this, the so-called "ultimate" navigation system.

The next issue of the RCAF OBSERVER will have a change of editor, but not a change in editorial policy. It is to be hoped that our readers will support the new editor by forwarding their views, whether they be of an operational, technical, or general nature.

INERTIAL

guidance

(PART I)

The term inertial navigation refers to "the art and science of finding velocity and position on the earth by sensing change of vehicle motion (acceleration) relative to the earth and integrating with respect to time." The basic physics formulae for motion state:

$$V = at \quad (1)$$

$$\text{and } S = \frac{1}{2} at^2 \quad (2)$$

$$\text{or } S = \iint a. dt^2 \quad (3)$$

This is the principle of inertial systems, which are entirely designed to solve these three simple formulae.

The principle of the system can best be seen if the following simple example is considered. A car starts at rest and accelerates uniformly at 10 ft/sec/sec, and then continues at a constant velocity. At the end of 5 seconds the car will be travelling at 50 ft/sec (equation 1), and will have travelled 125 feet (equation 2). Had the car been equipped with an accelerometer, and the output fed to a pair of integrators in series, the output from the second integrator would be distance in feet (equation 3). If the output voltage from the first integrator had been fed to a voltmeter, calibrated in feet, it would indicate speed in the same way as in the conventional speedometer.

The accelerometer is a device designed to measure the accelerations affecting a vehicle. To ensure that only those accelerations in a given direction are measured, the device is limited to one plane of freedom.

There are two principal types of accelerometer. In the first type, the inertial reaction force of the mass causes a displacement of the mass in an elastic mount. The displacement is then measured by any of several methods. The second type of accelerometer operates on a fundamentally different principle. The force that counteracts the inertial reaction force of the mass is not supplied by an elastic mount but is supplied by an electric current, a stream of air, or any other system which can produce a controllable force. In this system, a small deflection of the mass is detected, and a force is instantly applied to the mass to prevent any further motion. Acceleration is indicated by the magnitude of the force applied to the mass by the electric current, or whatever other means is used, to produce the balancing force.

Principle of the Accelerometer

Considering Figure 1; if the vehicle accelerates some distance "x", the mass "m" is displaced (relative to the frame) some distance in terms of "y". The relative acceleration of the mass during this time indicates force because:

$$F = Ma$$

Equation (4)

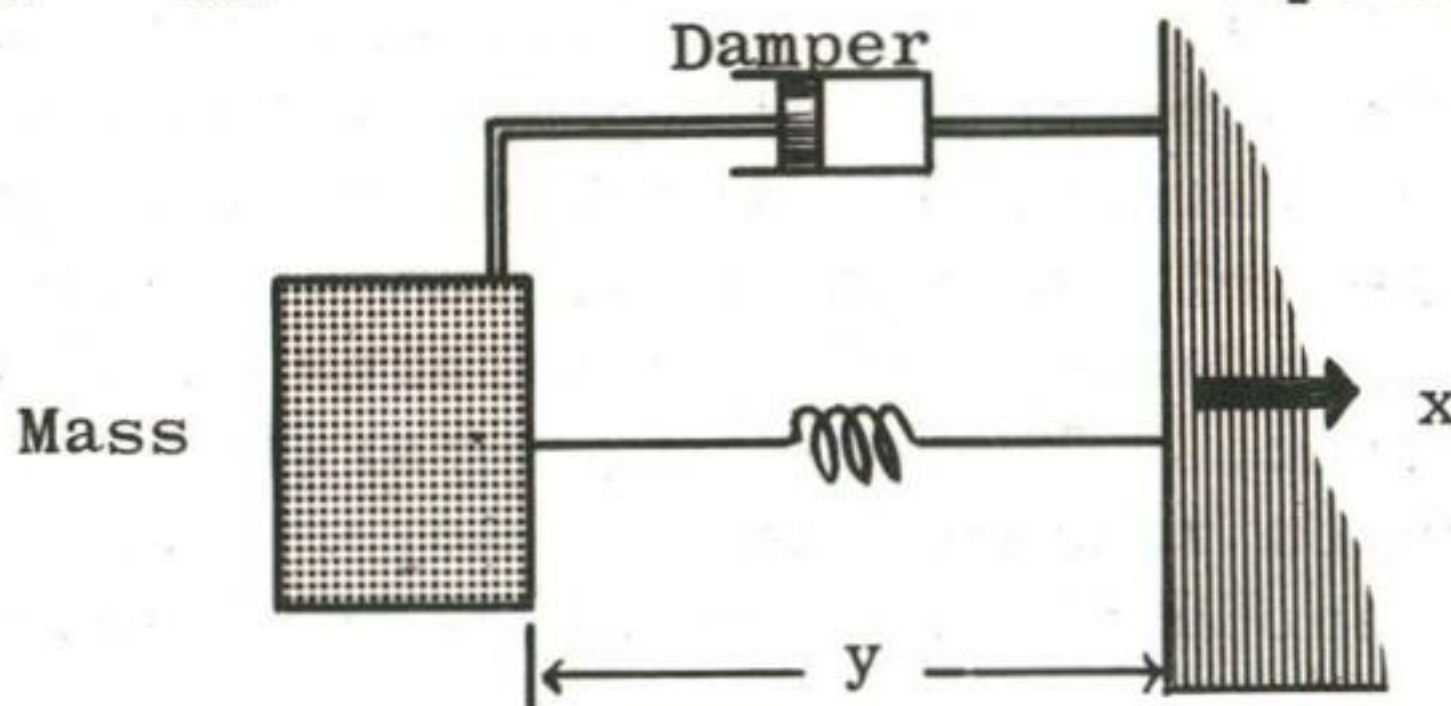


Figure 1

The simplest form of accelerometer is the moving mass type, which is similar to the device in Figure 1. In this device a DC potentiometer wiper is fastened to the moving mass and the amount and polarity of voltage provide the amount and direction of the acceleration (Figure 2).

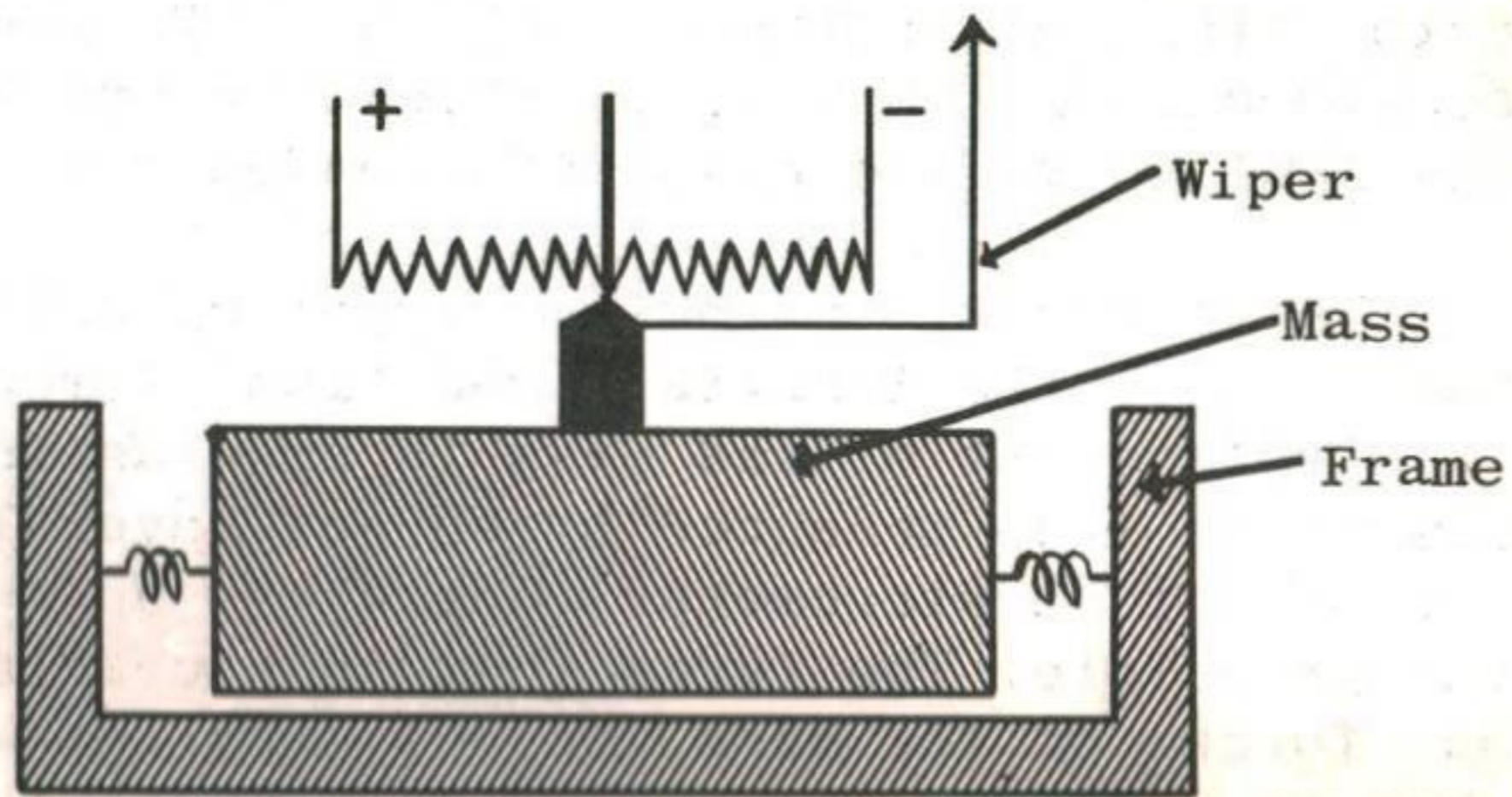


Figure 2

Another device makes use of a pendulum. The pendulum reacts to acceleration, with the amount of deflection of the bob being a direct indication of the acceleration (Figure 3).

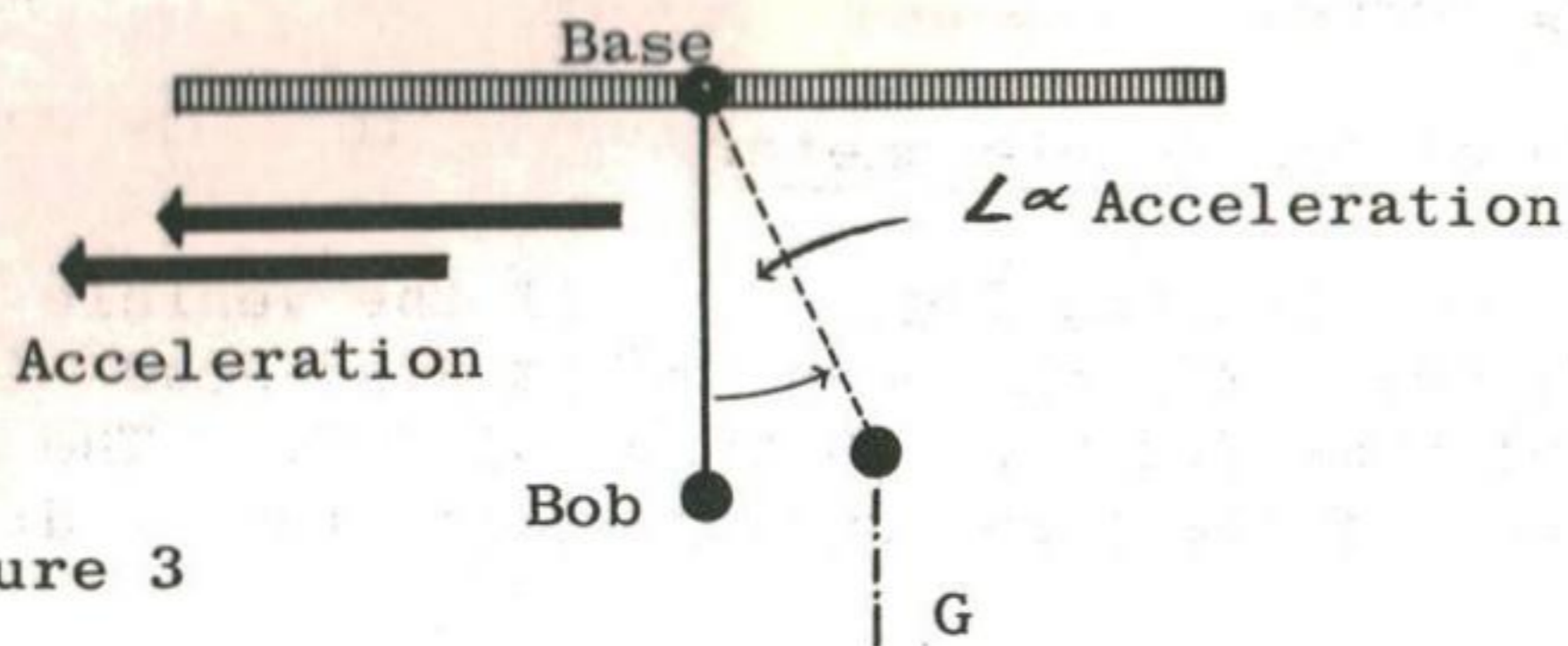


Figure 3

Actually, the design is impractical, because as the pendulum moves from the vertical, gravity affects the mass and opposes the acceleration. To eliminate this problem the counteraction type of accelerometer is used, the best example of which is the so-called "electric spring pendulum". A motor driven version has been produced which maintains the pendulum at its vertical position. The device consists of a small DC motor with a pendulum attached to the motor case (Figure 4), with the assembly supported in low friction bearings.

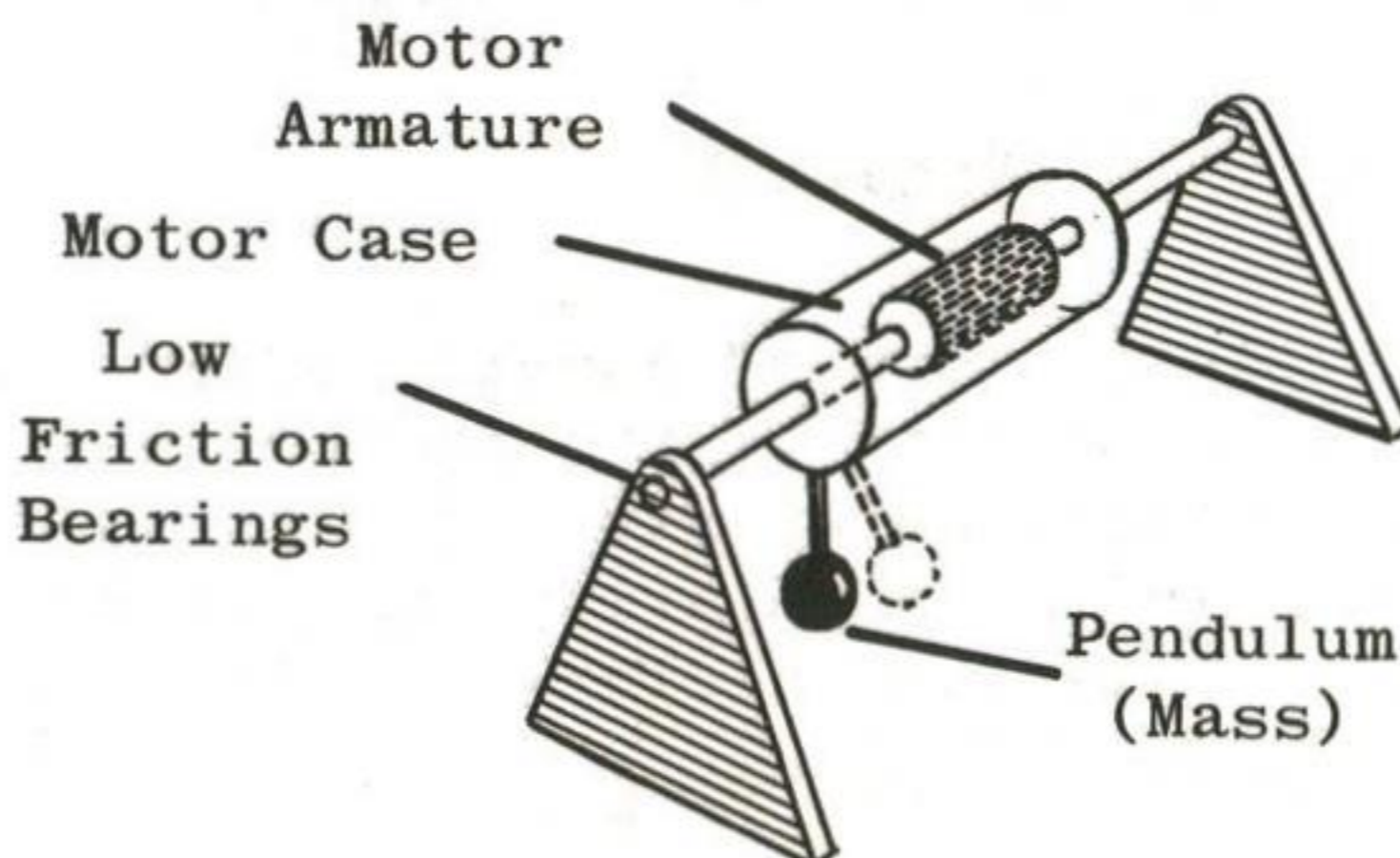


Figure 4

When the device is subjected to an acceleration, the mass and case rotate slightly. If this rotation causes power to be applied to the motor, rotating it in the opposite direction, the motion of the pendulum will be cancelled. The amount of control voltage required is a direct measure of the acceleration. Production versions of this device are reported to be highly satisfactory, being capable of measuring accelerations as low as .000005G.

The integrators must be designed so that once they have been set by an acceleration they continue to provide an output, until affected by a new acceleration. If this were not the case the output would stop when constant velocity is attained.

The Basic System

The basic components of the inertial system are as follows:

- The stable element, oriented to maintain the accelerometers in the horizontal.
- The accelerometers, arranged on the platform to sense specific components of acceleration.
- The integrators, which convert the acceleration to distance.
- The computer, which accepts the output of the second integrator and converts it to change of position in the selected co-ordinates.

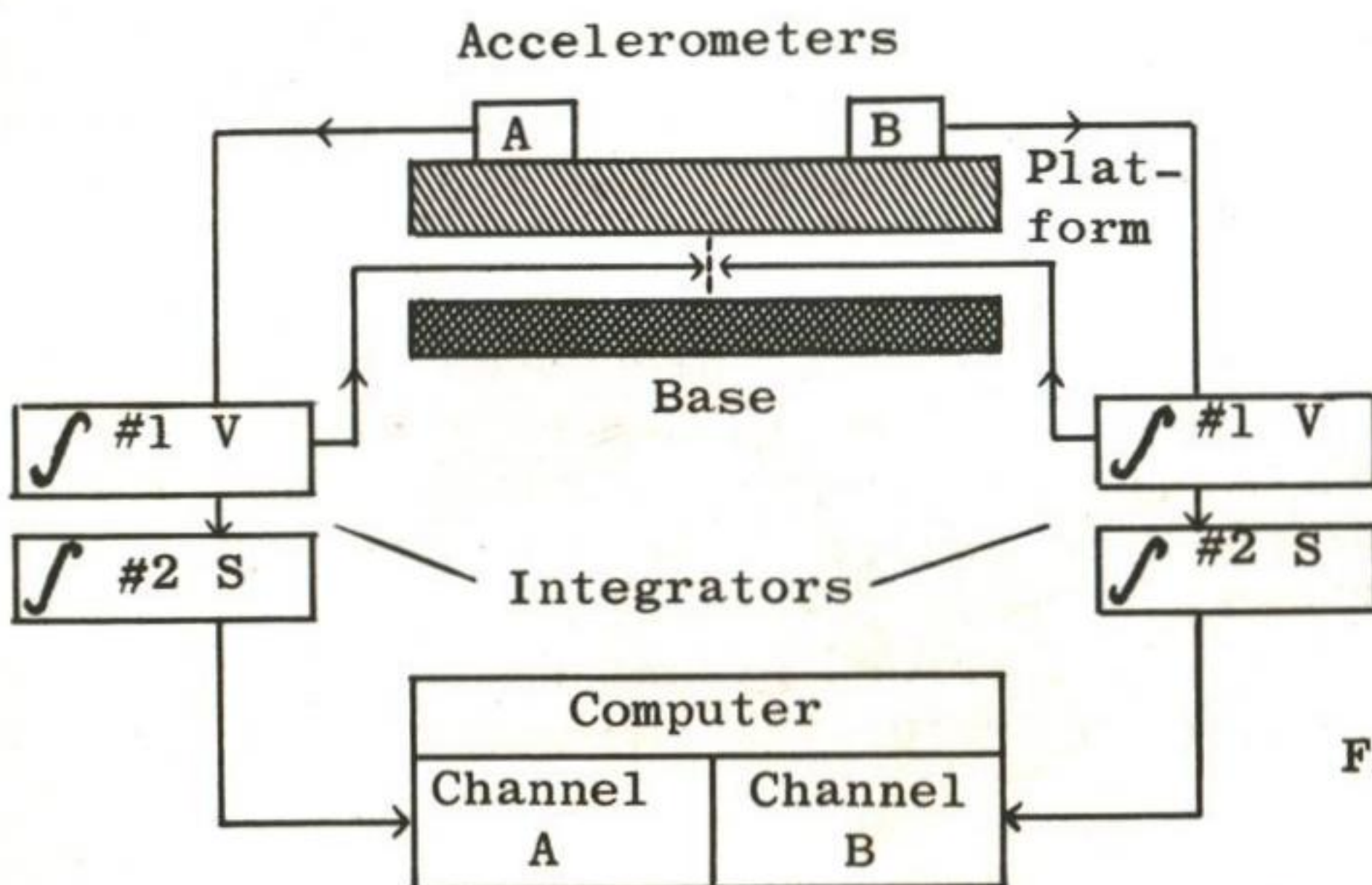


Figure 5

These components are illustrated in Figure 5. This is the simple form of the system and the actual linkage between the components, and the techniques used will be described later, when the problems and limitations have been discussed.

Co-ordinates Used

In any navigation system the choice of the co-ordinates in which position is measured, depends upon the nature of the navigation problem. For example, bomber aircraft require position in either latitude/longitude or along/across track, while a fighter requires position as bearing and distance from the controlling position (such as the GCI).

The three techniques used in inertial navigation are as follows:

Latitude and Longitude. Latitude and Longitude is the conventional technique of converting distance flown into change of position N-S and E-W. The problems associated with convergency at high latitude prevent its application for trans-polar operations.

Ninety Degree Offset System. The disadvantages associated with the latitude and longitude system are eliminated if a grid technique is used. The ninety degree offset system is so named because it is based on an earth graticule, offset so that the pole occurs at some position on the equator. This results in the polar areas being covered by a square grid. The computations associated with this system are very complex and must be solved using an automatic computer.

Guidance Plane Co-ordinate System. The guidance plane co-ordinate system is used for the special case of navigation between two specific positions on the earth. The system senses the accelerations along and across the desired track, providing distance flown along track, and departure from the desired course.

The first two conventional systems discussed above are ideal for standard navigation systems in manned vehicles, but if they are required to guide a missile, a course-and-distance computer must be added to generate the steering signals. The guidance plane system, however, is ideal for missile control, because the across track error signal can be used to energize the rudder controls, returning the vehicle to its planned trajectory.

FACTORS AFFECTING INERTIAL GUIDANCE

It has been explained earlier that the principle of the inertial guidance system involves measuring change of position through the measurement of accelerations. As the accelerometers are mounted on a stable platform, to exclude the effect of gravity, it should be apparent that the accuracy of the system depends to a large extent upon the effectiveness with which the platform defines the horizontal, and the accuracy of the measuring device and other components. In addition to these factors, however, several problems exist with navigation over the earth. Before proceeding further, these problems and errors should be examined.

The Platform

Unless the platform possesses a high degree of accuracy, the sensing accelerometer will "see" effects of gravity, and these 'G' accelerations will be interpreted as motion of the platform. The stable element must, therefore, be extremely accurate if the system is to be satisfactory. This implies the use of gyros with no random drift, a complete absence of friction in the gyros and gimbaling, and perfect control of the servo motors.

Components

The accelerometers and all components used in the system must be extremely accurate. Accelerometer accuracy can be best explained if it is considered that the average acceleration required to displace an object a distance "s" in "t" seconds, assuming zero initial velocity is:

$$s = \frac{1}{2} \cdot at^2 \qquad \text{Equation (2)}$$

where "s" is the distance in feet, "a" the acceleration in feet per second per second, and "t" the time in seconds.

The accelerometer sensitivity required for accuracy in a given system may be found by use of the above equation. For example, if a vehicle has a velocity of 1500 mph, the required time to travel 400 miles is roughly 960 seconds, and the average acceleration required to cause an error of 3000 feet in this time can be found by substituting the time and distance into the formula. This substitution would give the acceleration as 0.0065 ft/sec/sec. Therefore, if the acceleration is in error by 0.0065, all other errors being zero, there would be a system error of 3000 feet in 400 miles. In this example, the acceleration assumed was quite low. Accel-

erations as great as 500 ft/sec/sec may have to be measured, and the accelerometer must, therefore, be capable of satisfying either extreme of conditions. This means that the accelerometer must be capable of measuring one part in 100,000. At present, accelerometers capable of measuring one part in 1,000 are available.

Gravity

As was explained in the article on "Stabilized Platforms" in the April 58 issue of the RCAF OBSERVER, the gravity and true verticals coincide only at the poles and the equator, because of the earth's ellipsoidal shape. The effect of coriolis also affects definition of the vertical, changing from maximum at the equator to nil at the poles. These effects result, therefore, in the pendulum taking up a position that defines not true, but "apparent gravity". Local effects in the earth's crust such as large mountains and dense underground deposits also deflect the apparent vertical from its actual position.

Direction

The accelerometers are placed on their stable element and the platform aligned in the appropriate direction for the co-ordinate system being used. Definition of direction has a direct effect on the accuracy of the system, and must therefore be determined with extreme accuracy. The earth's magnetic field is an indefinite means of measuring direction because of its "lean" to the east with increased altitude, and the effect of local anomalies, such as are to be found near Kursk, Russia, and the Pilansberg Dyke System in southern Transvaal. In addition to these and other effects, the magnetic field itself is neither known, nor can it be set into the system with the accuracy required, making Gyroscopic direction mandatory.

Latitude

Considering the ellipsoidal shape of the earth, it can be seen that small discrepancies arise when latitude is considered. It is possible to develop three different latitudes for the same position because the earth is not a perfect sphere. Referring to Figure 6, geocentric latitude is the angle between a line through the centre of the earth and the equatorial plane. Astronomical latitude is the angle with the equatorial plane made by a line perpendicular to the earth's surface. Geodetic latitude is the same as astronomical latitude except for corrections in the direction of gravity due to local conditions. Although the effect of ellipticity causes a maximum difference of only 11 minutes between geodetic and astronomic latitude, a considerable error would result in the system if this were uncompensated.

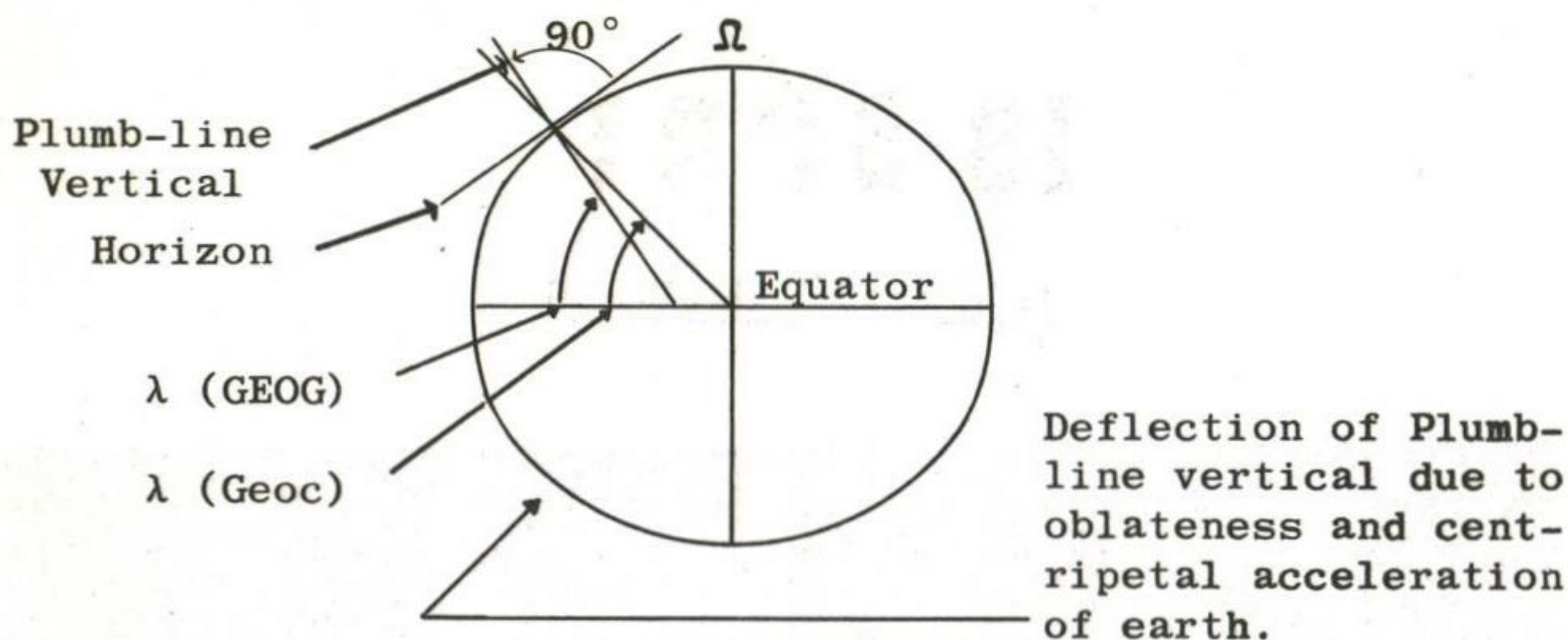


Figure 6

Great Circle

The great circle is the shortest distance between two points. Because the earth is not a perfect sphere, however, the True Great Circle is slightly elliptical, following the shape of the earth.

Earth Rotation

The earth is rotating on its axis, while revolving about the sun. The target is, therefore, moving with reference to inertial space and describes a complicated trajectory through that space. In actual fact the vehicle does not fly toward the target, but to a point in space at which it is predicted the target will be at the particular instant when the vehicle arrives.

Trajectory Analysis

The many forces and effects acting on the guidance system can cause considerable error because of the distances over which the long-range vehicle is operated. The problems discussed in the preceding paragraphs, and the difficulty in knowing the exact location of the target on the surface of the earth, present tremendous difficulties. The problem is solved in an application of mathematics termed 'trajectory analysis', in which the target position is adjusted to allow for all predictable effects, and the course to be steered is then obtained.

18 SORI

31 MAR 58 - 1 JUL 58

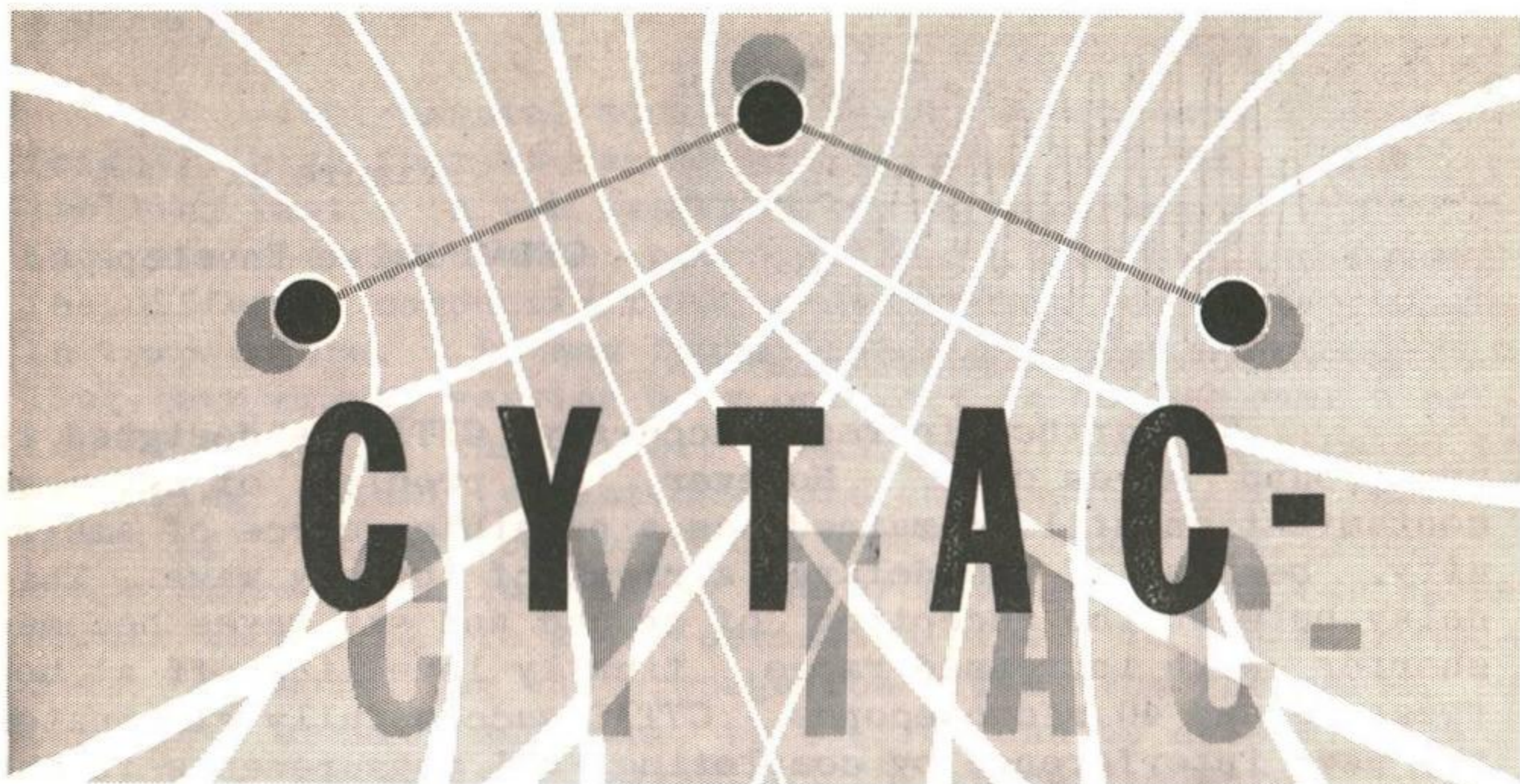


Back Row

F/L WD Lyall (Course Director), F/L ROJ Carey, F/L V Burdett,
F/L PHM Lavoie, F/O KFG Smyth

Front Row

F/O RMT Headley, F/O GW Duguid, F/O SW Waldegger,
F/O JGE Proulx



CYTAC, an accurate, long-range hyperbolic navigation system, was originally developed by the Sperry Gyroscope Company under the sponsorship of the USAF Air Development Centers at Rome, NY, and Wright, Ohio. It has since been field tested, and a contract has been given to Sperry to set up a CYTAC chain along the east coast of the United States. CYTAC has been tendered as a standard international, long-distance navaid.

Principle

Initially, CYTAC was called CYCLAN (Cycle Matching Loran), which more aptly described its operation. The present name was derived from its application to the requirements of Tactical Air Command.

The principle of CYTAC is essentially the same as Loran, with two major changes. The first is that it occupies a much lower portion of the frequency spectrum (90-110 Kcs) than Loran (1700-2000 Kcs), thus greatly extending the range. The second basic difference is in the method of measuring the time interval between the arrival of a master and a slave signal at the receiver. As in Loran, CYTAC first resolves a "coarse" time difference between the arrival of the pulses. This difference is then further refined by comparing the relative phase of the RF carriers within the pulse envelopes, which results in far greater accuracy than can be obtained from Loran. The rough determination of pulse time difference is sufficiently accurate to exclude any possibility of ambiguity in the phase comparison.

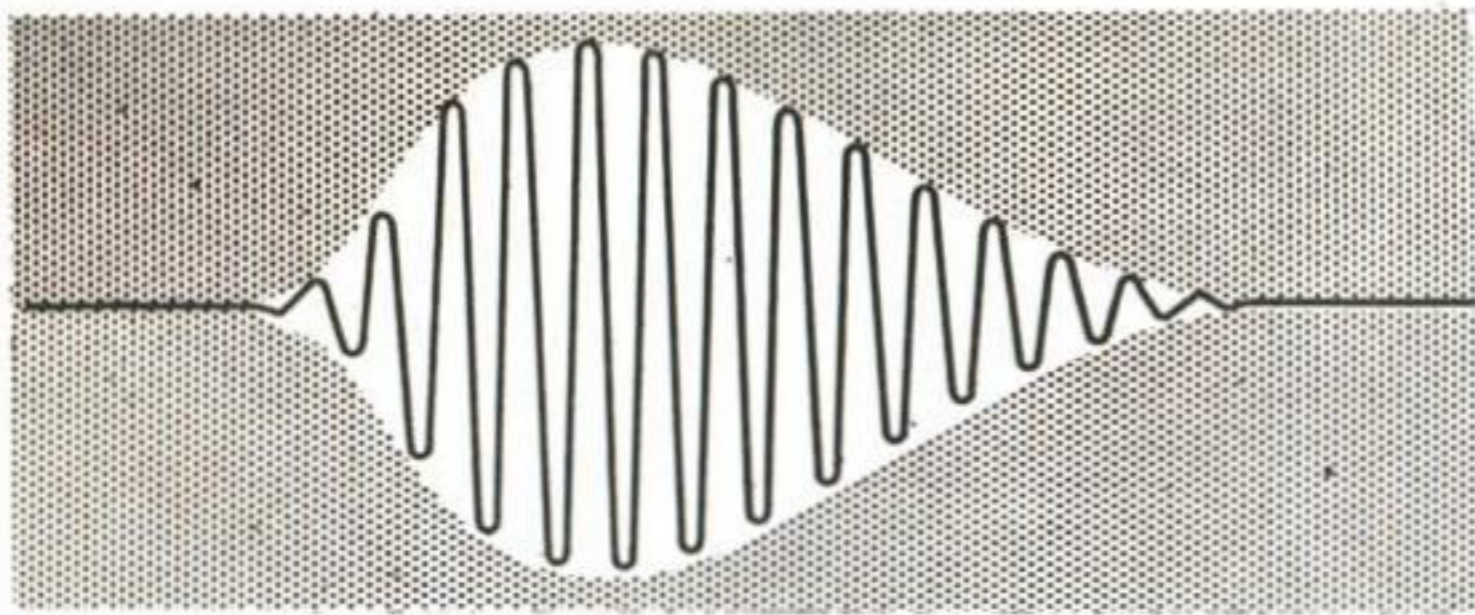


Figure 1
- CYTAC Pulse Envelope

To further increase accuracy, CYTAC is designed to use ground waves only. However, the problem of sky wave contamination still remained as a possible source of ambiguity, because of the delayed arrival of the sky wave. This delay between the reception of ground and sky waves becomes shorter with increased range, finally levelling off at between 30 and 40 microseconds. CYTAC successfully eliminates sky wave interference by completing all measurements in the first 30 microseconds of the ground wave, or before the arrival of the first sky wave (Figure 2). To accomplish this, a fast-rising transmitted pulse, with a maximum amount of power concentrated in the first 30 microseconds, is used. Thus the receiver can accurately measure the time difference 27 microseconds after initial reception of the ground wave, well before the first sky wave could arrive.

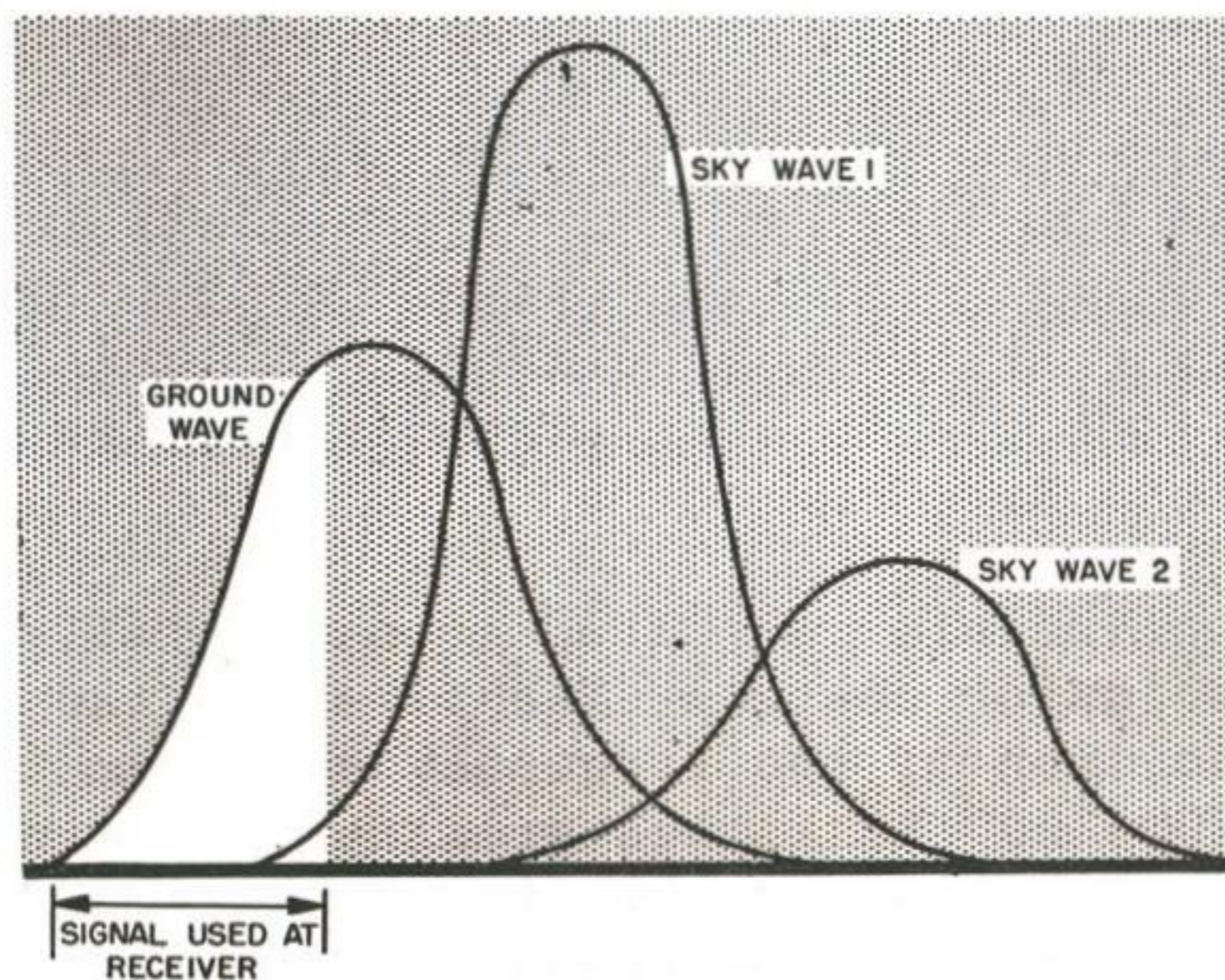


Figure 2 - Waveform of Received CYTAC Signals

Range

In field evaluation trials, CYTAC has been used successfully at ranges of 1200 nm, using power outputs varying from 60-200 KW. It is expected that this range will be increased to at least 1500 nm over both land and water, with a boost in power output.

Accuracy

Instrumental accuracy of fix measurement is sufficiently high that it can be disregarded in CYTAC. The controlling factor in the system's timing accuracy is the varying rate of radio-wave propagation. This has two causes: the differing conductivity of ground formations, and changes in temperature. It was found that the first of these is a long-term error, varying only one part in 50,000 over a period of a year. This error, then, could be eliminated by measuring actual variations and compensating for them by "bending" the lattices on CYTAC charts. Phase shifts due to temperature variations along the propagation path can cause errors amounting to a set deviation of 0.2 to 0.3 microseconds. By measuring the propagation time from the master to its slave station and back, this error can be determined, and the slave delay time adjusted to reduce the error to 0.1 microseconds.

Apart from these timing errors, there is another factor affecting accuracy; station arrangement has a large influence. The standard triad layout, seen in Figure 3, has two limitations. The first is that maximum accuracy is achieved on the base line, where an error of 0.1 microseconds in timing results in a position line error of 50 feet. As range increases away from the base line, the linear error increases so that at a distance of two base line lengths from the stations, the 0.1 microsecond timing error represents 200 feet. The second limitation is the decrease in the position lines' angle of cut with departure from the ground stations, which will further reduce fix accuracy.

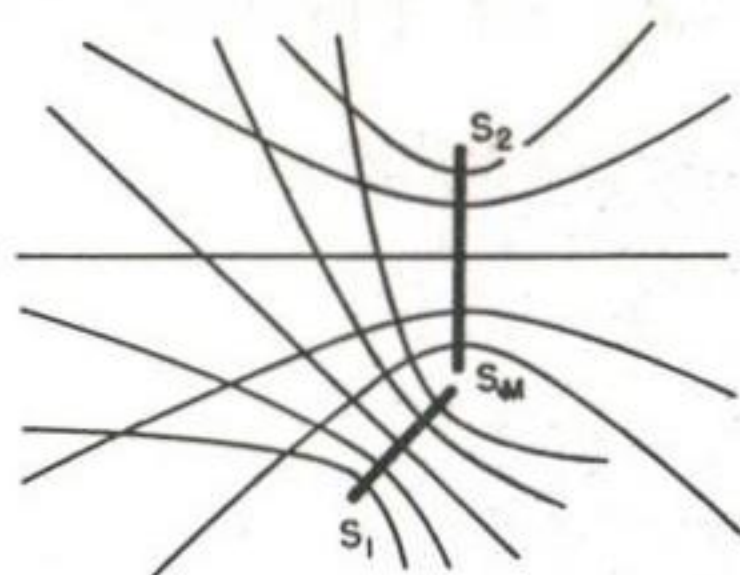


Figure 3 - Triad Station Arrangement

In both cases, accuracy is improved by increasing the length of the base line. A further improvement is obtained if a third slave station is added in either the star or square configuration shown in Figure 4, thus providing coverage in the otherwise unusable base line extension areas of the original triad layout.

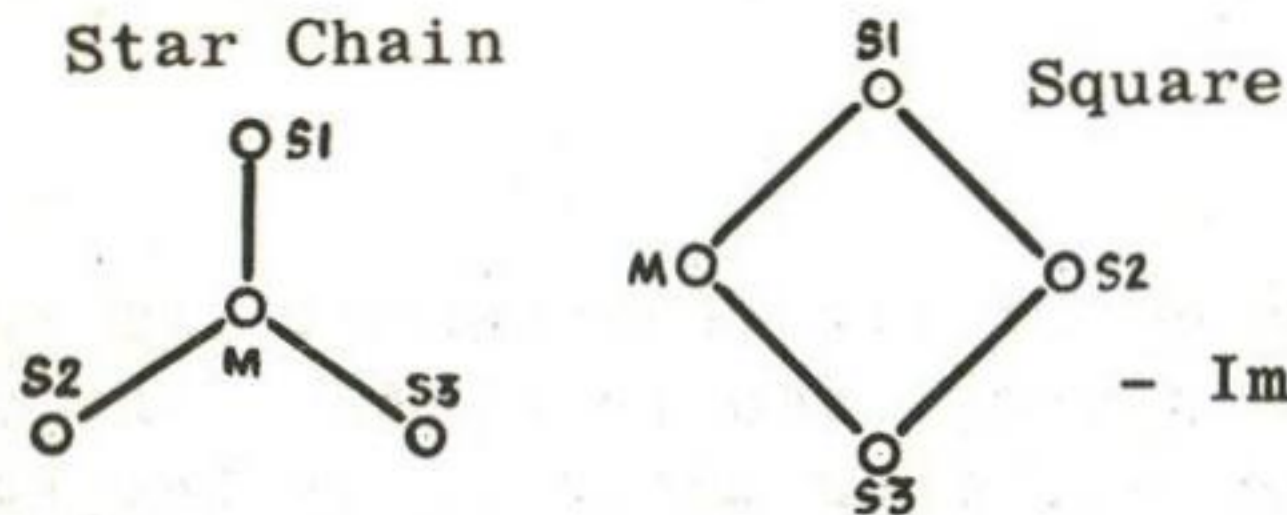


Figure 4

- Improved Station Arrangements

With appropriate base line lengths the square configuration can give a fix accuracy of about 100 feet in the area contained by the square.

Area Coverage

Fifteen CYTAC stations could cover the USA, Mexico, the southern half of Canada (up to about 55N), and 1,000 miles out to sea on both the Atlantic and Pacific coasts.

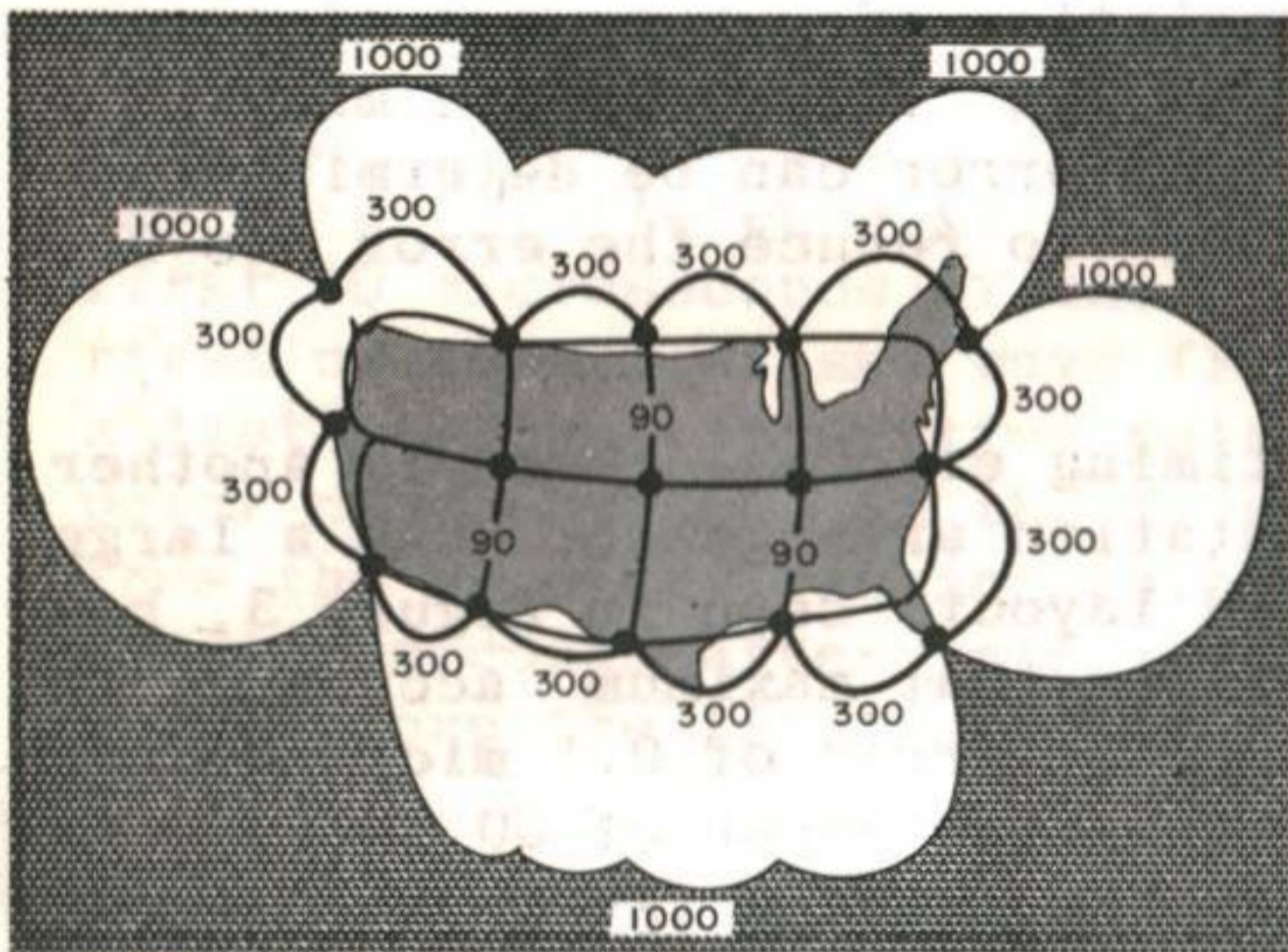


Figure 5

- North American Coverage

Position errors in this area of coverage should not exceed 300 feet, if trial results are borne out in widespread operation of the system.

Complete North Atlantic coverage could be achieved using two chains of four stations, while giving a ten-fold improvement in the accuracy of present Loran coverage.

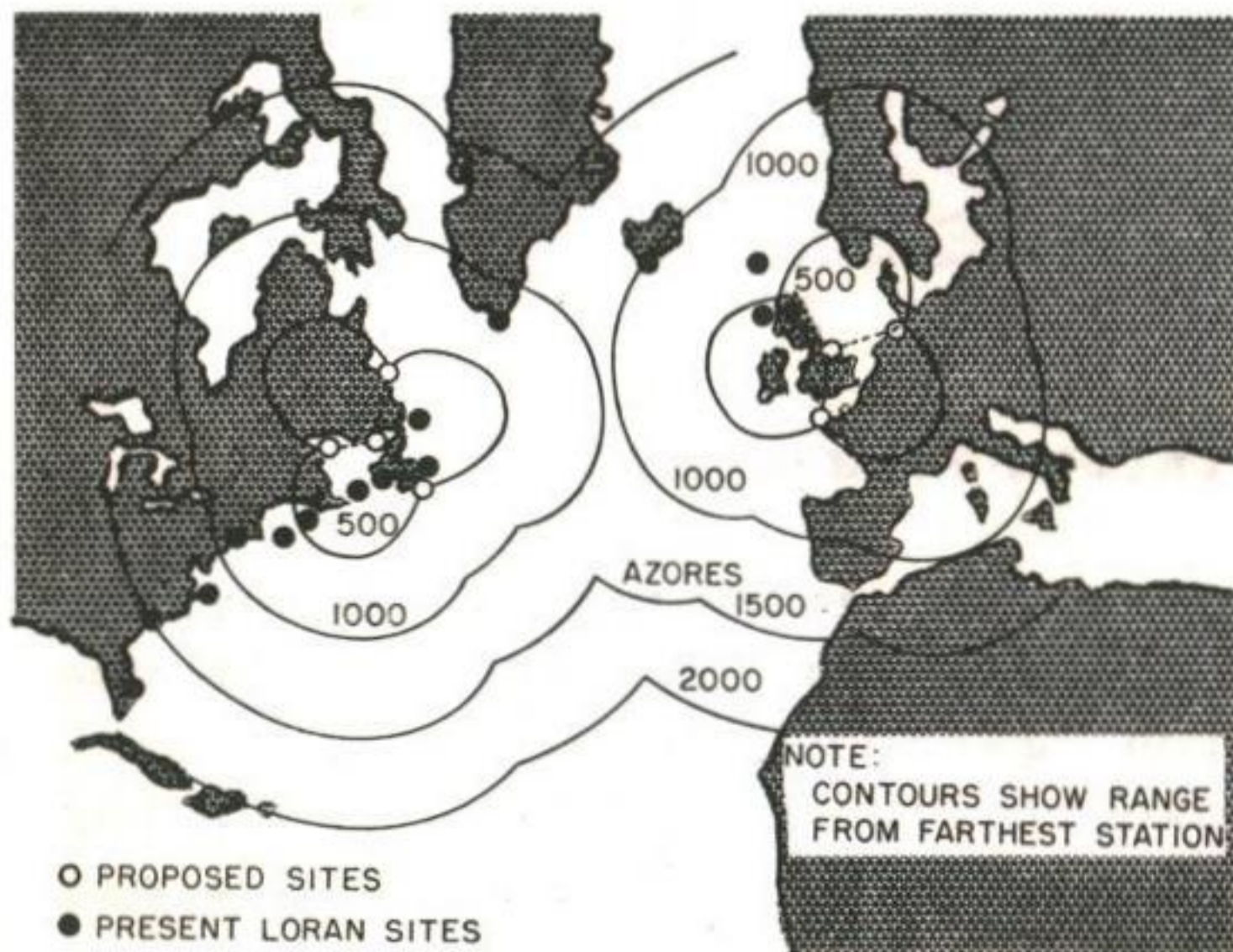


Figure 6

- North Atlantic Coverage

Reliability

The CYTAC receiver must of necessity be more complex than Loran sets. However, its accuracy does not depend upon either extreme stability of the components or intricate warmup and timing procedures, because all received signals pass through the same circuits, which are time-shared. Thus all signals are affected similarly, and the time difference remains unchanged.

It has been suggested that the combination of wide band-width and low frequency would make the system extremely vulnerable to thunderstorm disturbance. However, Sperry engineers report that there were no serious effects in a year of experimental operation.

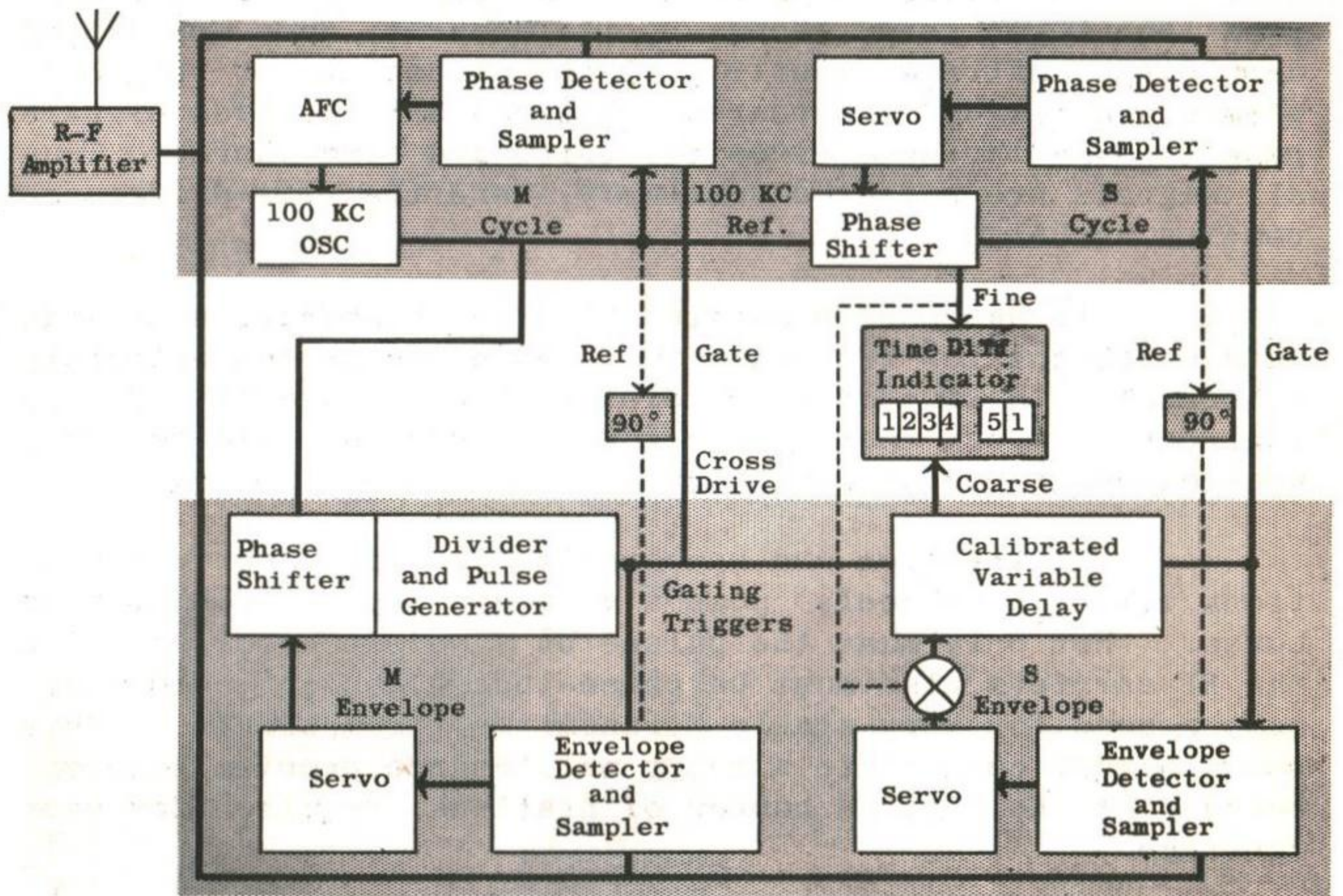
Calibration and synchronization of the ground stations will undoubtedly pose a more difficult problem than Loran. Not only must the pulses be time synchronized, but the RF carriers also must be phase-locked, which would indicate a need for very stable transmitter components. This would hardly constitute a major maintenance problem, however, because of the limited number of stations required for vast coverage.

Airborne Equipment

The experimental aircraft receivers used by Sperry present only time difference figures for a single position line, and the company has estimated that similar production equipment would weigh between 40 and 50 pounds. If desired, automatic plotting and display of aircraft position could be added, increasing the weight by 20 pounds. This weight is rather high for aircraft used solely in a domestic role, but a much lighter system may be possible, with slightly reduced accuracy. A block diagram of a CYTAC receiver is shown in Figure 7.

An interesting point is that present Loran receivers could quite easily be used for CYTAC with the addition of a frequency converter. Such a receiver would not be capable of phase comparison, but would provide the greater range and slightly increased accuracy resulting from the use of CYTAC's low frequency ground wave.

Figure 7 - Block Diagram of CYTAC Receiver



Conclusion

CYTAC offers wide area coverage with accuracy sufficient for both enroute and terminal requirements. Unlike VHF aids which are unusable at low altitudes, this system functions from the ground up; therefore, it can be used for marine, helicopter, and aircraft navigation. It is true that the weight of airborne equipment is rather high compared with high frequency aids, but is this really a penalty considering the accuracy and range achieved? The problem of calibration and synchronization of ground stations must be balanced against the small number of stations requiring such attention. The inevitable conclusion is that CYTAC is one of the most promising new aids to navigation.

2 SO(AI)I

26 MAY 58 - 5 SEP 58



Back Row

F/O PH Wojciechowski, F/O LA Dodd, F/O FC Brittain, F/O AJ Legg
F/O NH Anderson F/L JK Doiron, F/O LJ Raina

Front Row

F/O GE Emmerson, F/L GW Patrick (Course Director), F/O GA Dawson

RO

Instructor training

The past two issues of the RCAF OBSERVER have outlined the aims and content of the SO(AI)I and SONI courses. The third post-graduate Observer course, the Staff Observer Radio Instructor (SORI) has similar aims, which are as follows:

"To qualify aircrew list officers for appointment as a radio and electronics instructor."

"To provide a candidate with a knowledge of electronics and allied subjects, beyond the basic graduate level, so that the officer may be better qualified to assume appointments on squadrons, on operational training units, and in staff positions."

Allocation of Hours

The SORI course lasts seventeen weeks and, as for SONI and SO(AI)I students, the first two weeks are spent at the School of Instructional Technique (SIT). During the course the main emphasis is on those academic subjects which give the student an adequate background to understand the operation of present equipment, and to enable him to analyse new developments. A detailed allocation of hours is given in Table 1, and the subject content will be discussed briefly.

Assessment

The SORI student is only assessed on the academic subjects, receiving a mark out of 1000. Comments on the student's flying and instructional ability are, however, included in the narrative of the training assessment (PT4).

Procedure

The subject Procedure and Operational Organization is intended to review communications operating rules and procedures, and to outline the communications organizations. Topics include twelve hours on procedures used for Service C/W, Service D/F, civil D/F, and ICAO C/W, while the remaining six hours are devoted to distress procedures, and the organization of ICAO and DOT. Two hours are allocated for the examination, which has a value of 100 marks.

Aerodynamics

During the thirty-eight hours of aerodynamics instruction the student learns the problems connected with flight, engines, cruise control, and special aircraft types. Three hours of instruction are used to discuss the classification, controls, and warheads of contemporary guided missiles. A total of 100 marks is given in this subject, including a progress test and final examination.

Applied Navigation

The sixty-four hours allotted to applied navigation are really devoted to navigation generally. Of the total hours only twenty-eight are concerned with the triangle of velocities, computer manipulation, position lines, drifts, and plots, topics normally considered under the heading of applied navigation. The remaining thirty instructional hours are devoted to: instruments, astro, maps and charts, drift meters, gyros, sextants, astro compasses, direct reading and gyro magnetic compasses. While the subject appears somewhat superficial, it does provide the SORI student with an understanding of the navigation problem, and trains him to navigate the aircraft effectively. The final examination embraces theory and plotting for a total of 100 marks.

Electronic Theory

The one hundred and twenty hours devoted to electronic theory are intended "to provide the student with sufficient knowledge of electronic systems and circuits to enable him to operate electronic equipments efficiently and deduce the theory of operation of any electronic equipment." During the 107 instructional hours, the following general topics are discussed: fundamentals of electricity, tubes and amplifiers, communications systems, transmission lines, propagation, microwave techniques, and radar systems. Two examinations are given in this subject for a total of 300 marks. Five hours, which are non-examinable, are used for a discussion of new developments and design problems of airborne equipment.

Communications Equipment

The communications equipment discussed during the SORI course are the SCR 211, SCR 237, AN/ART-13 and 15, SCR 274N, AN/ARC-3, AN/ARC-38, and frequency synthesis equipment. A total of 100 marks is allotted to the progress test and examination given during the thirty three hours of instruction.

Aids to Navigation

Aids to Navigation parallels the subject of Electronic Equipment on the SONI syllabus. During the twenty-three instructional hours the following topics are covered: D/F equipments, radio range, AW/ARN-6, VOR/DME, DECCA, TACAN, SCR-718, AN/APN4 and 70, AN/APS-33, AN/APS-42, AN/APG-33, SARAH, and sonobuoys. This subject receives 100 of the one thousand examination marks.

Mathematics

The mathematics portion of the syllabus is identical to that given for the SO(AI)I course, covering algebra, measurement of angles, logarithms, and plane trigonometry. The mathematics training is fundamental to many other subjects on the course; eligible personnel would be well advised to obtain an algebra text for pre-course study.

Meteorology

The meteorology training is intended to review the standard practices and procedures for meteorological services to aviation. It should also provide the student with an adequate background to permit him to evaluate briefing information and observed meteorological data as it affects communications and radar equipment. In addition to the thirty-two instructional hours, the student attends a daily weather briefing, increasing his knowledge of applied meteorology.

Morse

During the twenty-eight hours allotted to morse practice the student is expected to reach a standard of 22 words per minute (wpm). Many students graduate with a speed of 25 wpm.

ECM

Only eleven hours are devoted to discussing active and passive countermeasures, analysis, and communications jamming. No examination is given in this subject.

Instructor Training

In addition to the 80 hours spent at SIT, the student is given 49 hours of instructor training while at CNS. Topics include the organization of appropriate RCAF units, service writing, and observer training. The four hours of radio trainers listed under academic subjects are also a form of instructor training because the time is spent monitoring an applied radio officer course, under the supervision of an AOS instructor.

Flying

Six flights are normally made during the course, with the student acting as navigator, radio officer, and radar operator. Two of the flights are usually made enroute to a training or operational unit at which the students see some aspects of advanced aircrew or groundcrew training.

Administration

Student administration provides time for signing in, sports, time-off after night flying, holidays, the visit to a training unit, and clearances.

Conclusion

This has been a brief introduction to the SORI course, intended to provide all observer trades with an appreciation of the training. It has, of necessity, been of a general nature, and eligible personnel are reminded that the syllabus of instruction, CAP 464-E 10, is distributed to all RCAF Flying Units in Canada and should be consulted for further details of the course.

TABLE 1 - ALLOCATION OF HOURS

SUBJECT	HOURS	SUBJECT	HOURS
<u>ACADEMIC</u>		<u>FLYING</u>	
Procedure and Operational Organization	20	Flying	36
Aerodynamics and Guided Missiles	38	Briefing and Analysis	8
Applied Navigation	64	Total Flying	44
Electronic Theory	120	<u>INSTRUCTOR TRAINING</u>	
Communications Equipment	33	Instructor Training	129
Aids to Navigation	26	<u>ADMINISTRATION</u>	
Mathematics	32	Student Administration	99
Meteorology	32	Total Hours (17 weeks)	680
Morse	28		
Radio Trainers	4		
ECM	11		
Total Academic Instruction	408		



RADAR SCOPE INTERPRETATION

In our first discussion of factors affecting radar scope appearance we covered equipment design characteristics. These are factors over which we have some control. Equipment designers are continually attempting to achieve the narrowest beam, the smallest spot and the shortest pulse which will give acceptable results. For this reason we are able to measure accurately, and thus predict how our returns will appear on the scope with respect to these factors.

But this is not the whole picture! What of the shape, size, relationship, density, location and reflective qualities of the targets on the ground? Surely these must be considered! The terrestrial and cultural features are the targets that we are looking for, but they too have many deceptive qualities. For instance one single feature, by virtue of its isolated position, may reflect a much larger return than two comparable structures within a large target complex. Let's have a more detailed look at this facet of the problem.

The radarscope picture, in essence, is a map formed by energy reflected from the terrain being scanned by the radar beam. This portrays the relative amounts of energy reflected from the individual targets and elements of the surrounding cultural and terrain features. What we see on the scope then, depends not only on the physical characteristics of the reflecting objects but also on the position of the aircraft relative to those objects and, finally, on the ever present human element, the skill and experience of the operator in the use of set controls.

It should be stated at the beginning of this discussion that most of the factors we will deal with are of an indefinite nature. They must be considered, but because of this indefinite nature, they are difficult to compute. For example, cultural features are changing daily all over the

world because of new construction and ever-expanding cities. The operator must therefore be fully prepared for the new and unexpected.

The factors affecting our scope presentation conveniently divide themselves into two categories. These are:

→ Signal Potential, which is the ability of cultural terrain features to reflect radar energy, and

→ Signal Strength, which is determined by altitude, axis or bearing of the aircraft to the reflecting surfaces, and the use of gain controls and manual antenna tilt by the operator.

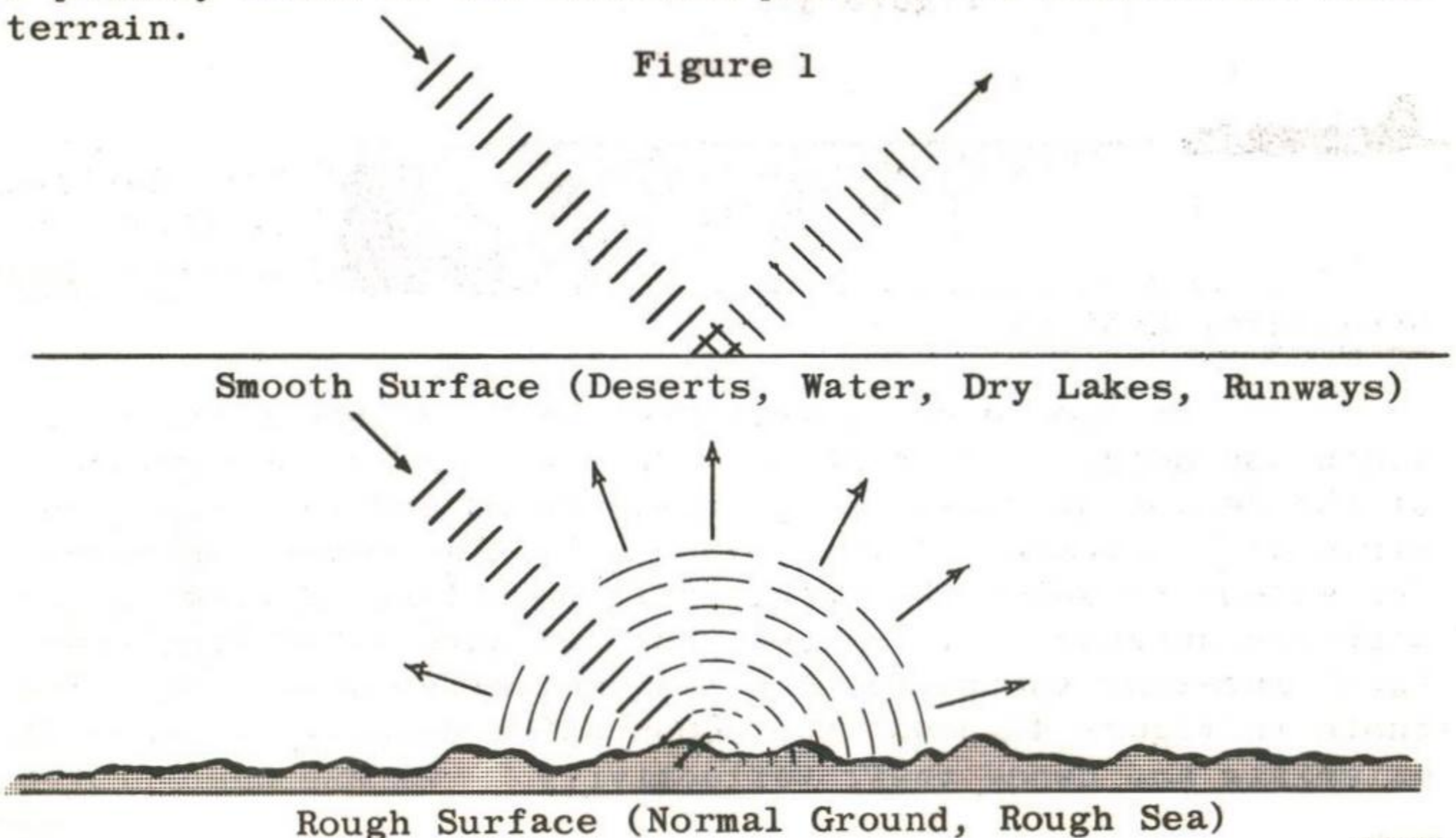
SIGNAL POTENTIAL

The factors that affect signal potential include surface condition, size, structural content, shape and the relationship to reflecting objects.

Surface Condition

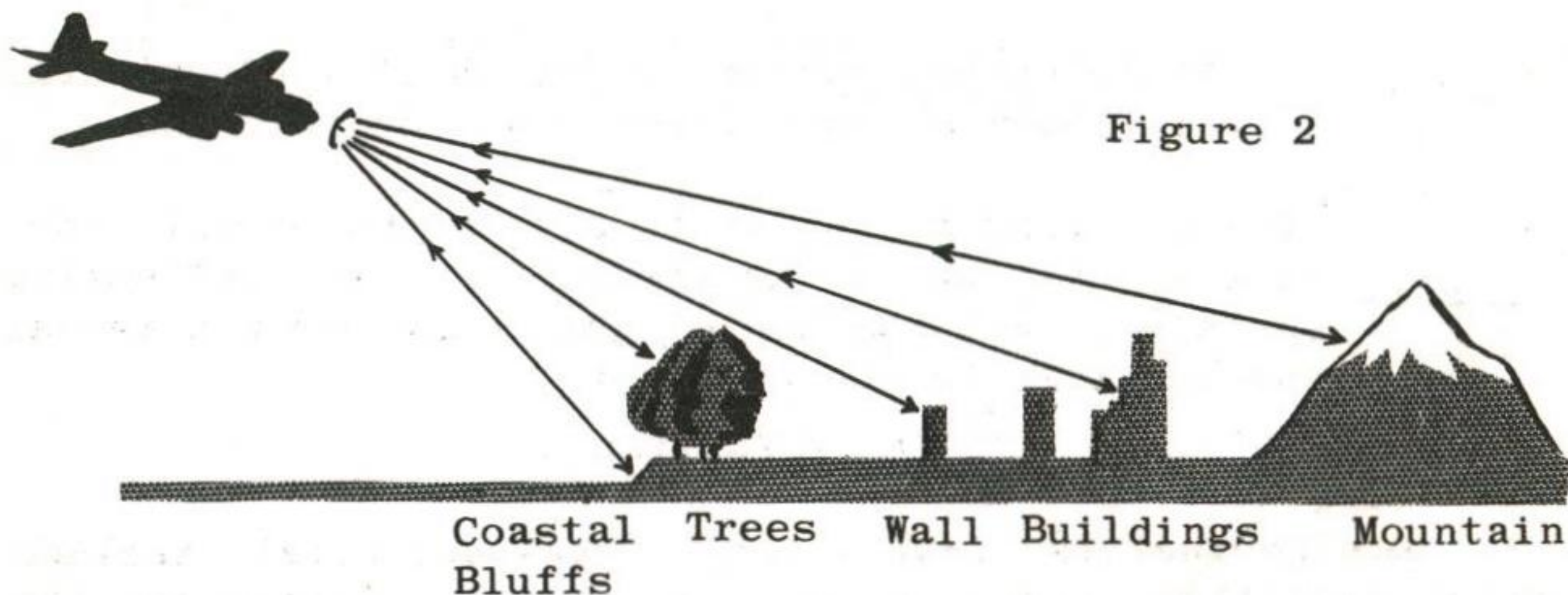
Contrast between rough and smooth earth surfaces is one of the most important means by which radar presents its information. Smooth surfaces such as calm seas, dry lakes or runways, reflect the radar energy away from the receiver and appear as black or "no show" areas, whereas a rough surface will scatter the energy in all directions and some will be returned to the radar antenna. In addition to the surface irregularities of land areas, vegetation is also a primary cause of the diffused pattern of reflections from terrain.

Figure 1



Size

Any feature that extends above the surface will reflect more energy than flat terrain. The amount of energy reflected is, of course, dependent on the width and height of the object (Figure 2).



Any variations in the intensity of returns from cities occur where there are buildings which vary greatly in size (Figure 3).

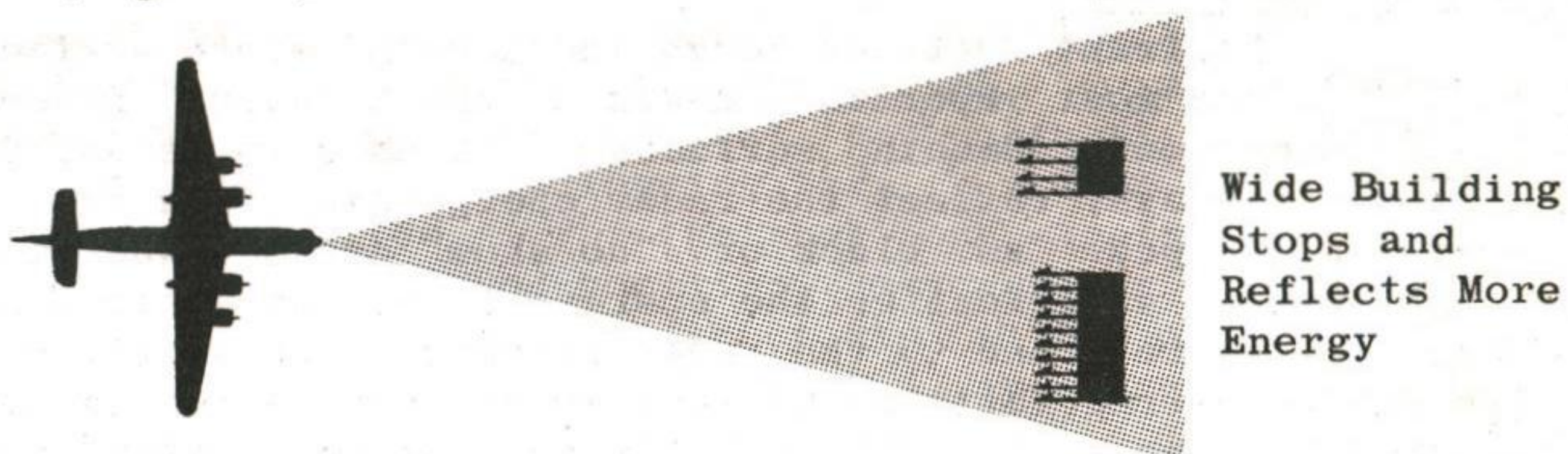


Figure 3



Structural Content

It should be remembered that although the size, width and height of an object are the primary determinants of the amount of radar energy interrupted and reflected, the structural content of the object will also govern somewhat the extent to which the energy will be reflected back to the airborne antenna. It follows that the more dense the structural material the better are its reflective qualities. The table in Figure 4 shows the comparative density of several materials and hence their reflectivity. It has been proven

that the less dense materials will tend to absorb more of the radar energy, and thus do not reflect as well as dense materials. An interesting fact is that the reflectivity is not entirely dependent on the surface materials used on the object. A wooden covered building, with a steel frame, will have more signal potential than an all-wooden building.

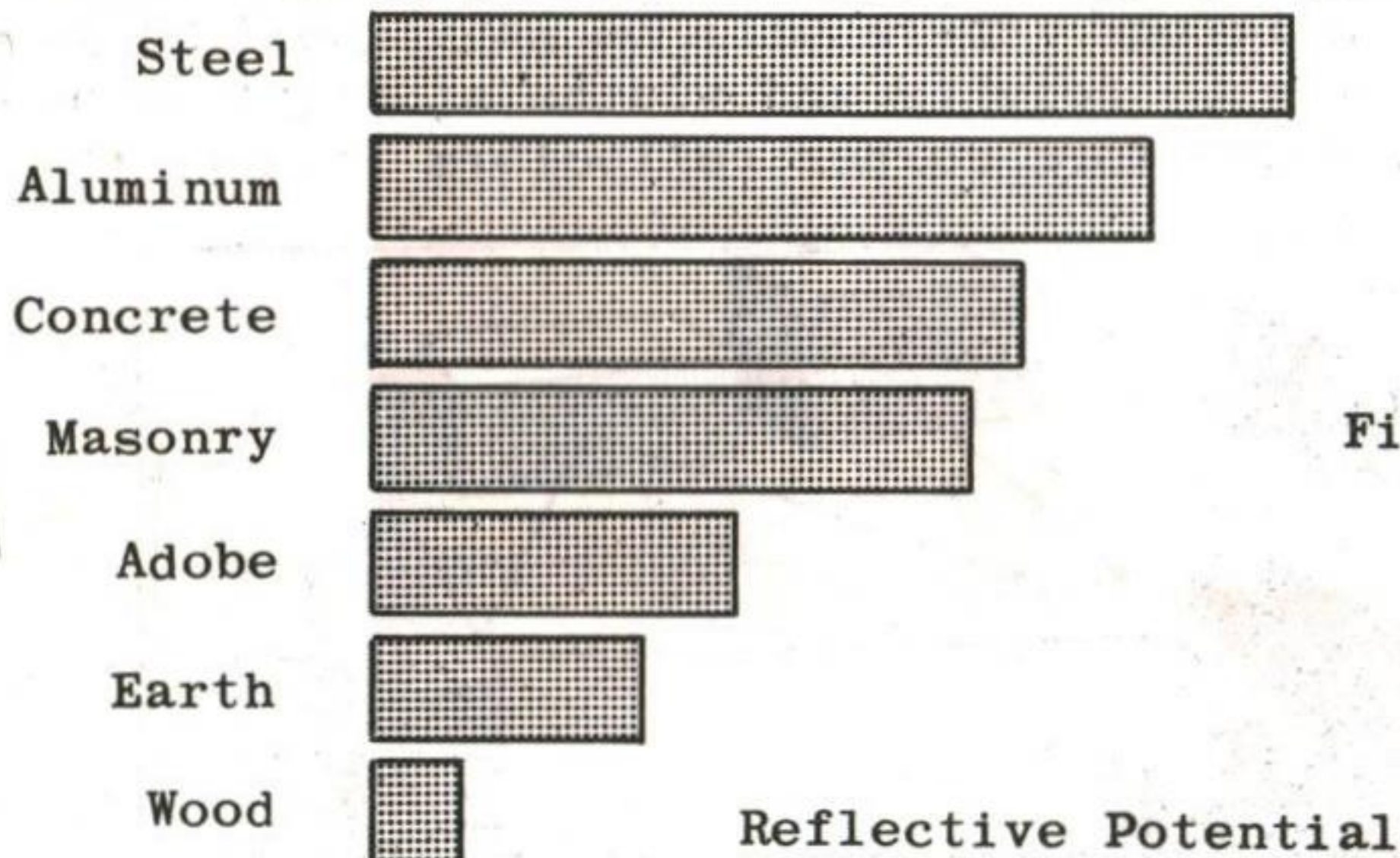


Figure 4

Shape

Most structures in cultural areas are rectangular or square and present good reflecting surfaces. The amount of energy reflected back varies with the angular reference to the beam (Figure 5).

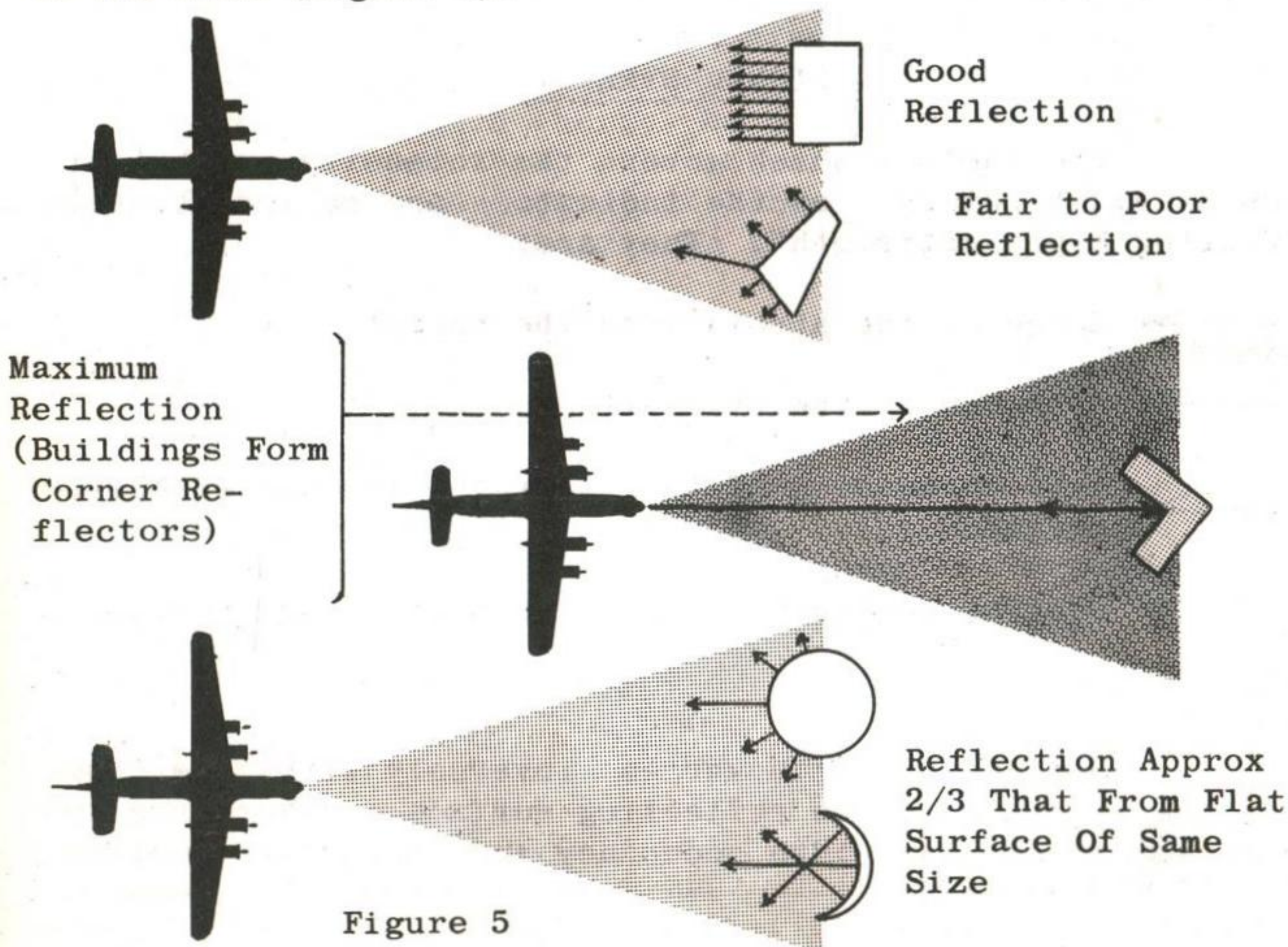


Figure 5

Relationship

Many operators have been puzzled in the past because the radar returns from man-made structures are often too strong to be solely from the solid angles intercepting the radar beam. This can be explained by taking into account the relation of the reflecting objects to each other. Amidst most groups of buildings there will be many combinations of surface areas, sizes, heights and widths at right angles to each other, and these form corner reflectors (Figure 6).

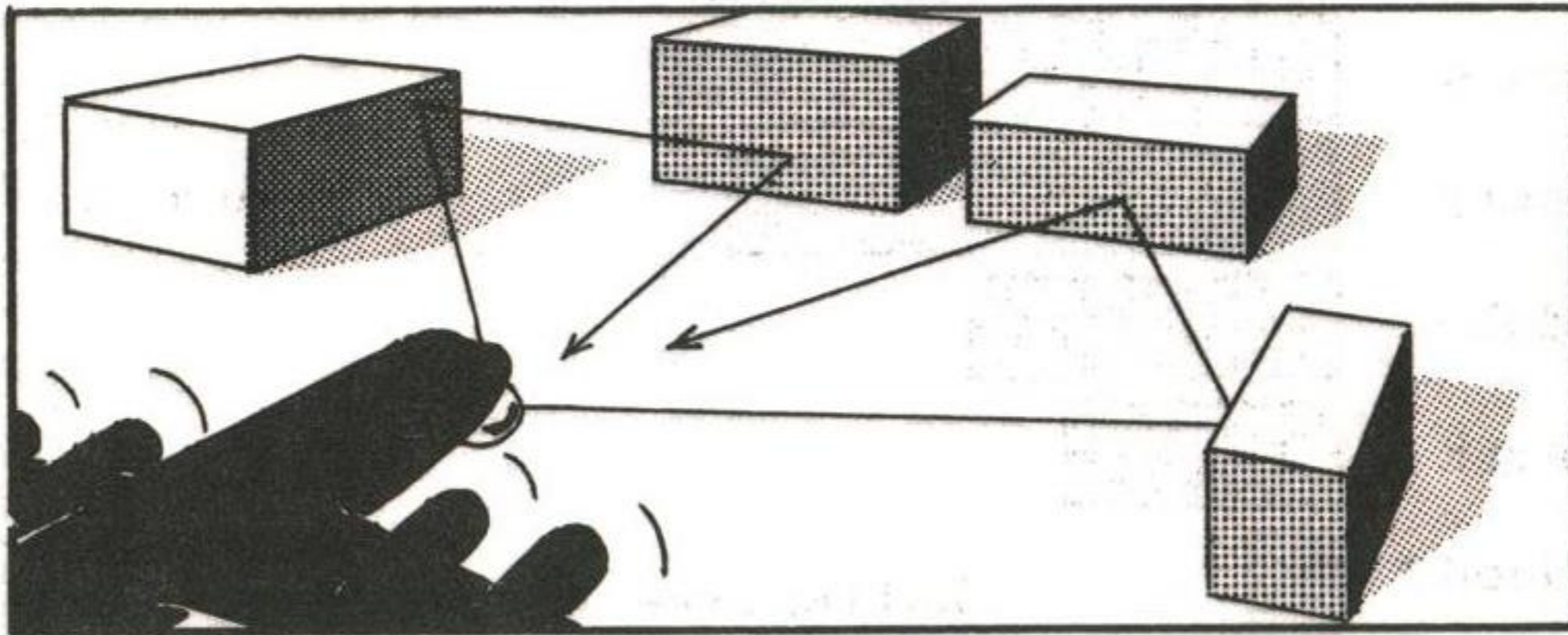


Figure 6

We have up to this point considered cultural and man-made features affecting radar scope presentation. These are called "Factors That Affect Signal Potential."

SIGNAL STRENGTH

The factors which govern the intensity or brightness of radar returns on the indicator are called "Factors Affecting Signal Strength". They are:

- Range of the aircraft to the target
- Altitude of the aircraft
- Axis or heading of the aircraft to the reflecting surfaces
- Control settings, such as gain and antenna tilt.

Range

Signal strength varies inversely with the range from the aircraft to the reflecting surface. There are two causes of this: beam width occupancy and energy attenuation.

The radar energy is focussed by the antenna into a beam of predetermined width in the vertical plane. Using a typical angular dimension of $1\frac{1}{2}^\circ$, we see that the radar beam subtends a larger area at increasing distances. Referring to Figure 7, building A occupies the entire beam at 10 miles, but it intercepts only one-third of the beam at 30 miles and reflects correspondingly less radar energy.

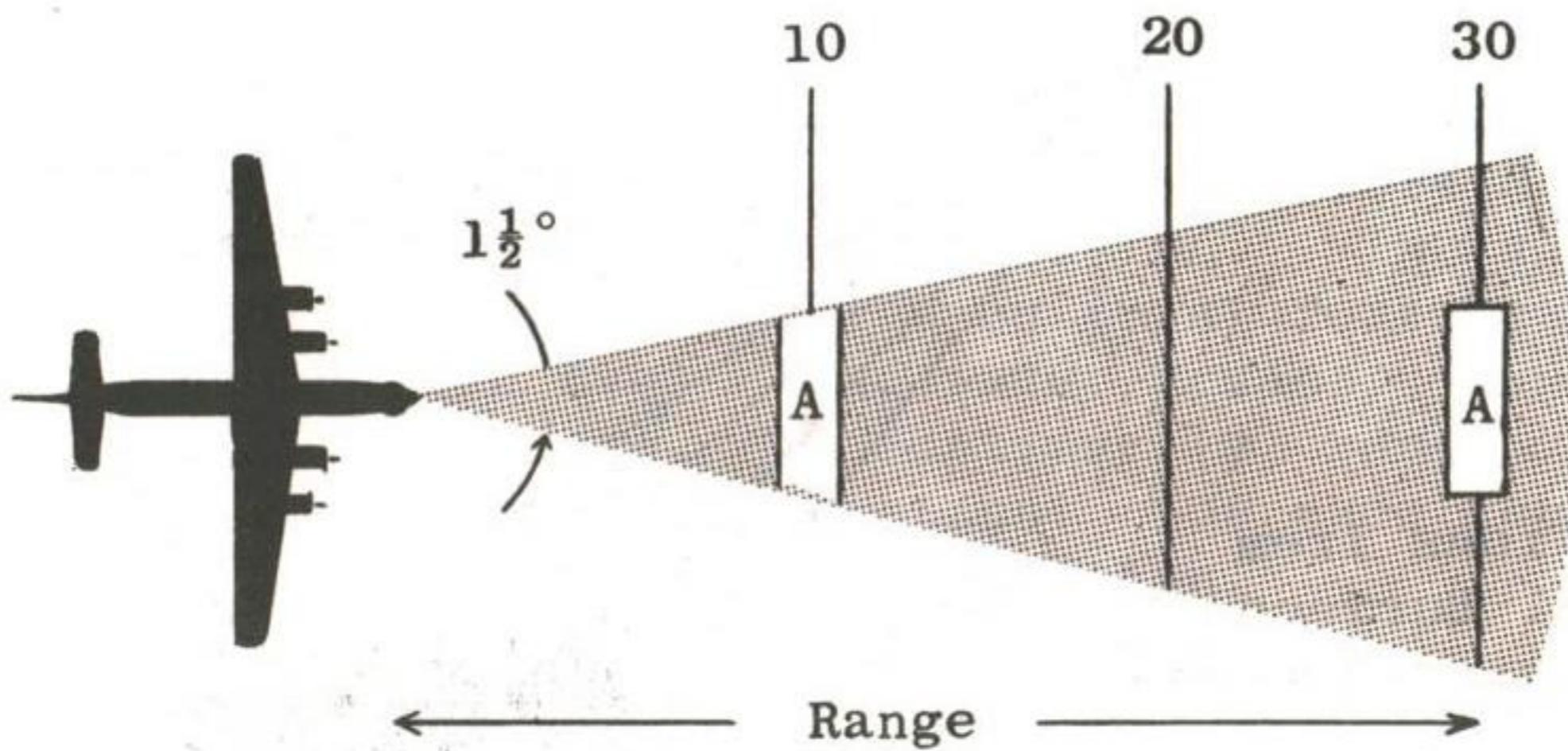


Figure 7

Radar energy is subject to range attenuation which diminishes the energy, by the fourth power of the range, to the target. For example, to receive the same signal from a target at 20 nm as from a target at 10 nm would require that sixteen times as much energy be directed to the target at 20 nm. To overcome this, the antennae used today have been designed to focus more power at longer ranges and they will produce a fairly even picture on the scope at all ranges.

Altitude

Since radar range is really slant range (a product of altitude and ground range as shown in Figure 8), then any increase in altitude increases signal attenuation; however, except at short range, altitude has relatively little effect on the magnitude of slant range compared to ground range.

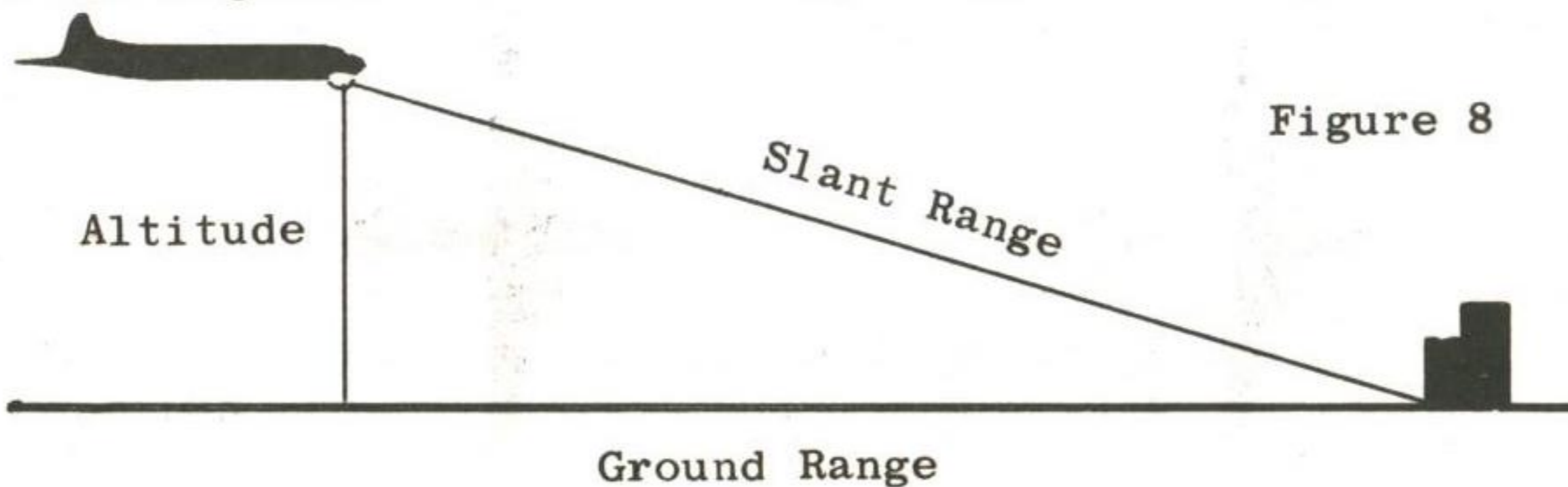
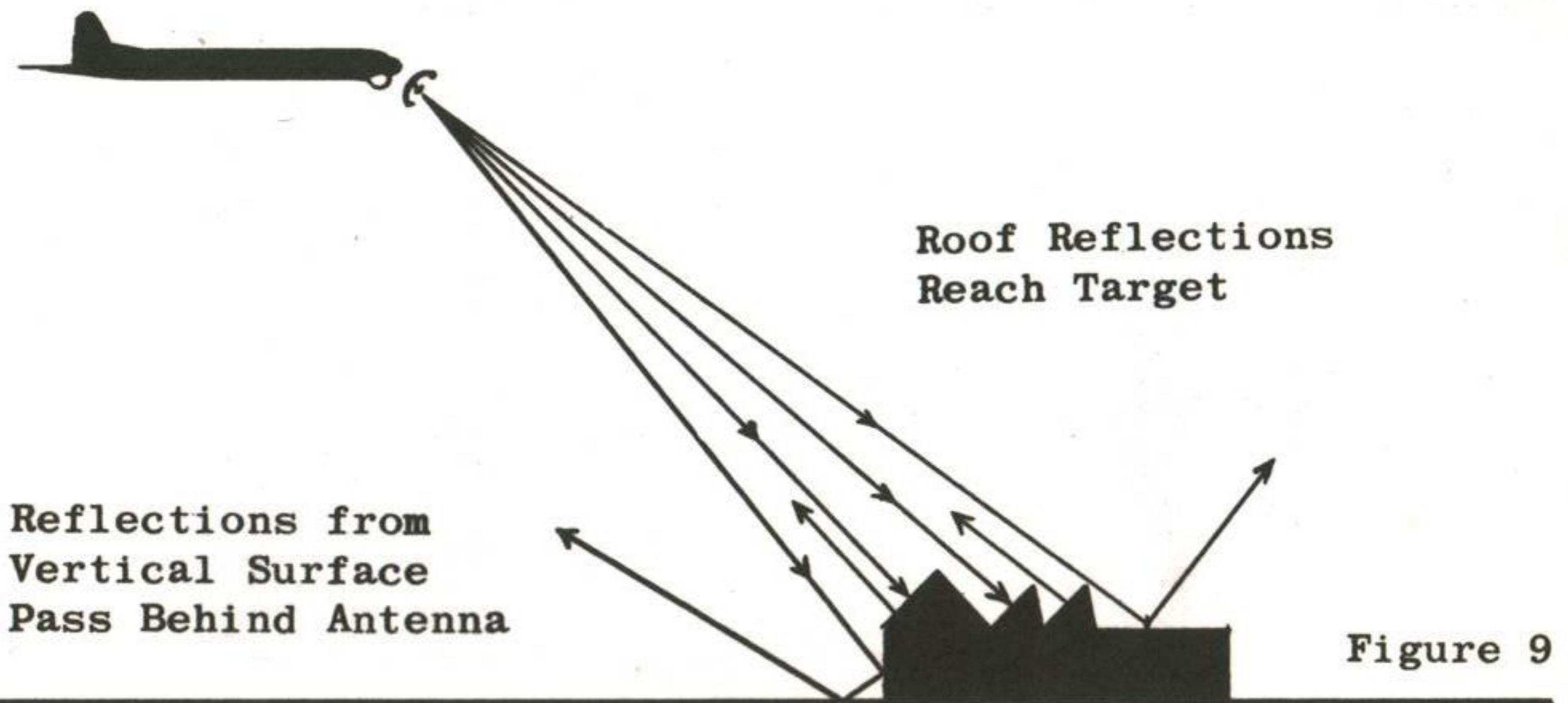


Figure 8

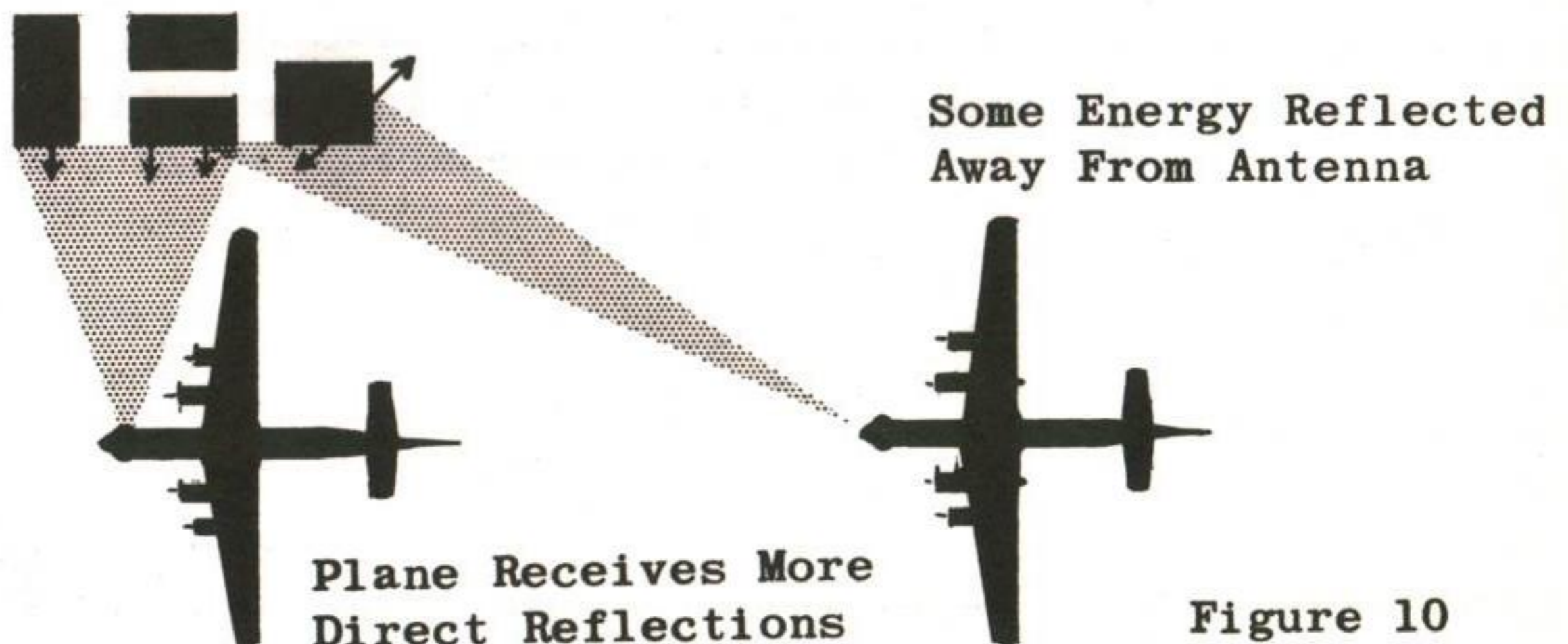
The primary effect of aircraft altitude is to change the angle at which radar energy strikes reflecting targets. This is most noticeable at short ranges, when the angular relationship between the radar beam and the object changes so that the vertical surfaces are no longer the primary reflectors, but the roofs are (Figure 9).



This usually occurs when the slant range is less than twice the altitude, and generally decreases the intensity of the reflections from cultural returns. Conversely, the returns from terrain features will generally be stronger because the radar energy strikes the ground at a greater angle as the altitude increases.

Axis

The axis, or the bearing of the aircraft to the reflecting targets, determines the angle at which the radar beam will strike the reflecting surfaces. As the aircraft moves over the ground, the relationship of the beam to the target changes and produces a fluctuation in the shape and intensity of returns on the scope (Figure 10).



In extreme cases, a change of aircraft position can so completely alter the appearance of returns from large cultural areas that some confusion as to the density will occur, especially when the target structures are oriented in a uniform direction.

Gain

The receiver gain control on a radar set is the same as the volume control on your radio. It determines the amplification applied to received radar signals portrayed on the indicator. If properly used, the receiver gain control allows the operator to obtain the proper presentation needed to fulfill the requirements of his mission. The adjustment required for the best picture from cultural features differs from that needed when over land-water areas. Experienced operators will, therefore, be continually readjusting the receiver gain to get the best contrast for each topographic detail to aid in radarscope interpretation.

Here are some helpful hints in the use of general gain settings:

- High Gain settings give maximum contrast between land and water when coastline features are used for identification. However, if the gain is too high, the scope will become over-saturated, and it would be difficult to detect small variations in intensity.

- Medium Gain settings eliminate the weakest scope signals and produce maximum definition of most cultural targets.

- Low Gain settings allow only the strongest and most persistent returns to show, and are usually used for pin-pointing, bomb runs and the like.

Antenna Tilt

To produce a ground-map picture, the transmitter focusses a narrow vertical beam of energy extending outward from a point below the aircraft, and revolves this beam through 360°. To compensate for range attenuation, the power decreases from a maximum at the leading edge of the beam to a minimum at the trailing edge. The vertical deflection of this beam, shown in Figure 11, can be varied up to 35° by tilting the radar antenna.

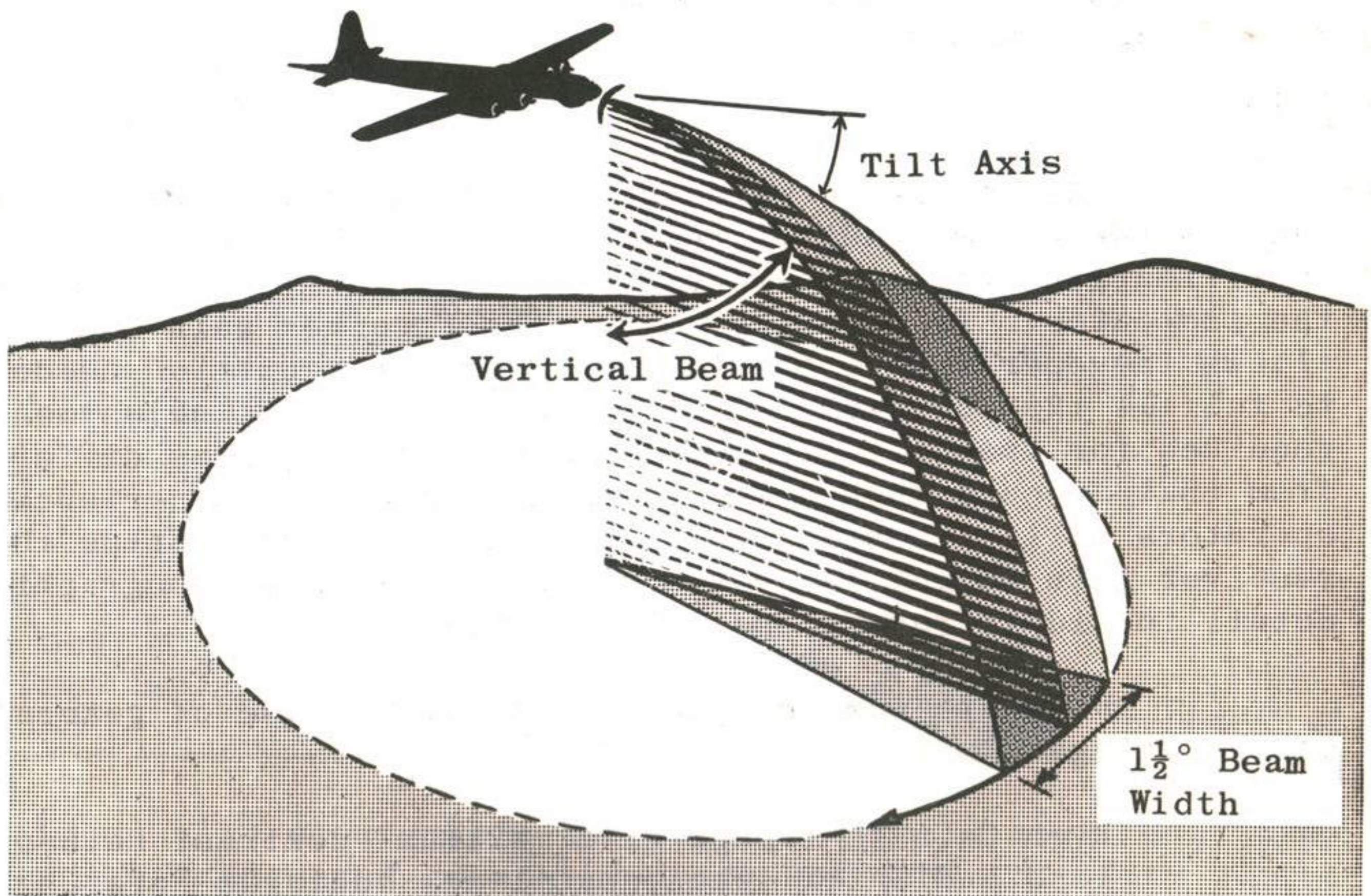


Figure 11

Each antenna for each radar set is designed for an operational altitude to obtain an optimum scope picture at that altitude. For different altitudes and when varying the range, the operator must use the manual tilt control to get the desired returns. This is particularly critical at the shorter ranges and only many hours of experience on the set can produce consistently good results.

SUMMARY

To get the maximum information from a radarscope, the operator must be able to interpret his picture not only in terms of the physical features of the reflecting terrain, or Signal Potential, but he must also consider the factors affecting Signal Strength.

You will find it relatively easy to turn a radar set on and get a picture on the scope, but you must be able to operate the equipment intelligently and interpret the scope correctly. The ability to interpret any radarscope competently will come only with much training and practice.

19 S O R I

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Back Row

F/O JAR Creamer, F/O WG Dunlop, Capt CE Evans (Course Director)
F/O FC King, F/O JWR Smith.

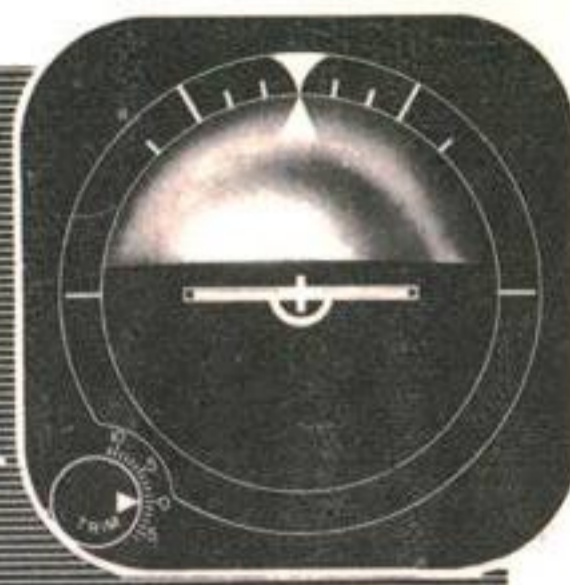
Front Row

F/O RJJ Lamont, F/O FJ Saunders, F/O PAA Lepage
F/O LC De Freitas

The Pilot's Instruments



BENDIX



Integrated Flight System

The Bendix Flight Director System was designed to simplify the pilot's task of flying high-speed aircraft in dense traffic. The primary purpose of the system is to provide position and attitude information so that it can be interpreted at a glance. Secondly, it presents to the pilot the pitch and roll corrections necessary to return the aircraft to the desired flight path.

The Flight Director System uses only two instruments to display the following information: gyro compass, VOR-OMNI, ILS, attitude, and command. The components of the basic installation are:

- Course Deviation Indicator
- Horizon Director Indicator
- Flight Director Computer
- Horizon Director Amplifier
- Vertical Gyro
- Phase Adapter and Rate Cut-Off

For full operation, inputs are required from a standard VHF navigation receiver, an ILS receiver, and a compass or directional gyro system.

The Course Deviation Indicator and the Horizon Director Indicator form the basis of this instrumentation. The supplementary instruments suggested to complete the "basic six" are a mach-airspeed indicator, an altimeter, an RMI, and a rate of climb indicator.

Course Deviation Indicator

The Course Deviation Indicator provides the pilot with a plan view of his flight progress. When used as an ILS indicator, it also gives glide slope indications.

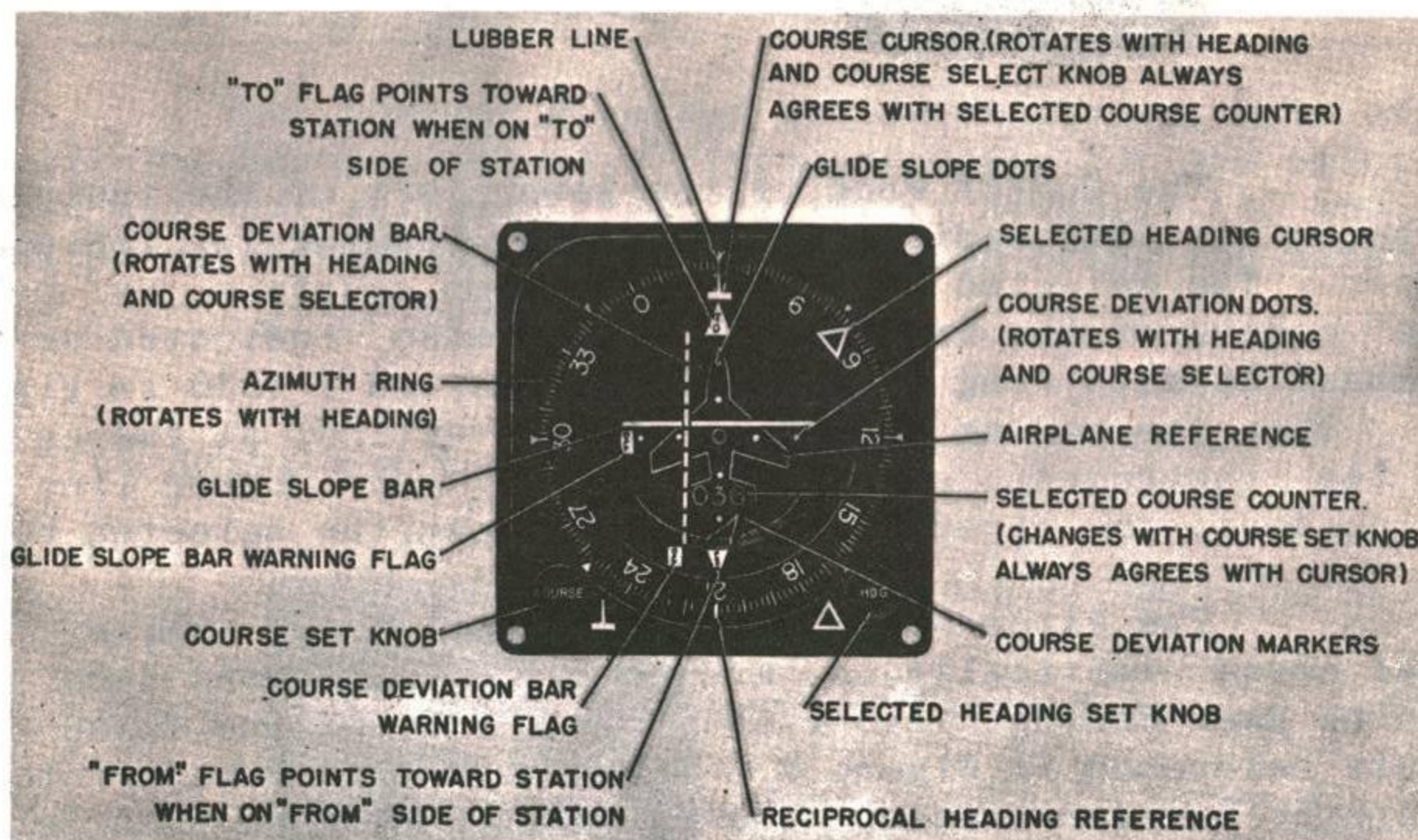


Figure 1 - Course Deviation Indicator

The heading indication is given by a rotating azimuth ring, marked in two degree increments, which is read against a vertical lubber line at the top center of the instrument. A triangular heading cursor rotates over this azimuth ring to indicate desired heading, which is selected by the HDG knob located at the bottom right of the indicator face. When this cursor is coincident with the lubber line, the aircraft is on the desired heading.

The course deviation bar is a broken white line, normally vertical at the center of the instrument face. When in operation, this bar pictures the angular and lateral displacement from a localizer beam or OMNI radial. The lateral displacement is shown by the amount the bar moves away from the center of the instrument (circle on fixed aircraft reference), and the aircraft heading relative to a chosen beam is shown by the angle the bar makes with the vertical center line. In Figure 2 then, the aircraft is well starboard of the beam, and approaching it at an angle of about 45° .



Figure 2

- Course Deviation Bar

The COURSE knob at the lower left of the indicator selects the OMNI radial, or the runway heading for ILS operation. The selected heading is shown on counters just below the center of the instrument, and is also indicated on the compass azimuth ring by a rotating, inverted T (030 in Figure 2). When the course deviation bar is vertical at the center of the instrument, and the inverted T and lubber line are coincident, the aircraft is tracking down the selected beam.

The glide slope bar is a horizontal white line that moves vertically up and down the instrument face. It can be seen coming into view at the nose of the fixed aircraft reference in Figure 2. When this bar is superimposed over the center circle, the aircraft is on the ILS glide path. The bar is entirely hidden from view when the glide slope receiver is not operating.

The two solid triangular flags at the top and bottom of the dial in Figure 1 indicate the direction of the VOR station from the aircraft. Only one shows at a time, and when the instrument is inoperative or being used for ILS, they are both hidden.

Two conventional warning flags, normally hidden, indicate malfunction of either the course deviation bar or glide slope bar.

Should the compass system become unserviceable, the course deviation indicator may still be used by pulling the COURSE knob out from the case front, thus putting the system on emergency operation. In this function, the course selection mechanism is disengaged, the compass dial is isolated, and the COURSE knob drives the rotating portions together so that their relative positions do not change. The pilot can then align the course deviation bar parallel to the vertical axis of the instrument without altering the desired course setting, and still use the course deviation display.

The Course Deviation Indicator is a very compact instrument only four inches in diameter, yet it provides the functions that previously required a gyro compass indicator, an OMNI bearing selector, and an ILS indicator. In addition, it gives added accuracy to ILS indications.

Horizon Director Indicator

The Horizon Director Indicator serves both as an artificial horizon and as a flying director for the pilot. It shows him what attitude the aircraft is actually in, and indicates which manoeuvres are required to bring the aircraft to a preset flight path.

Pitch and Roll Indication

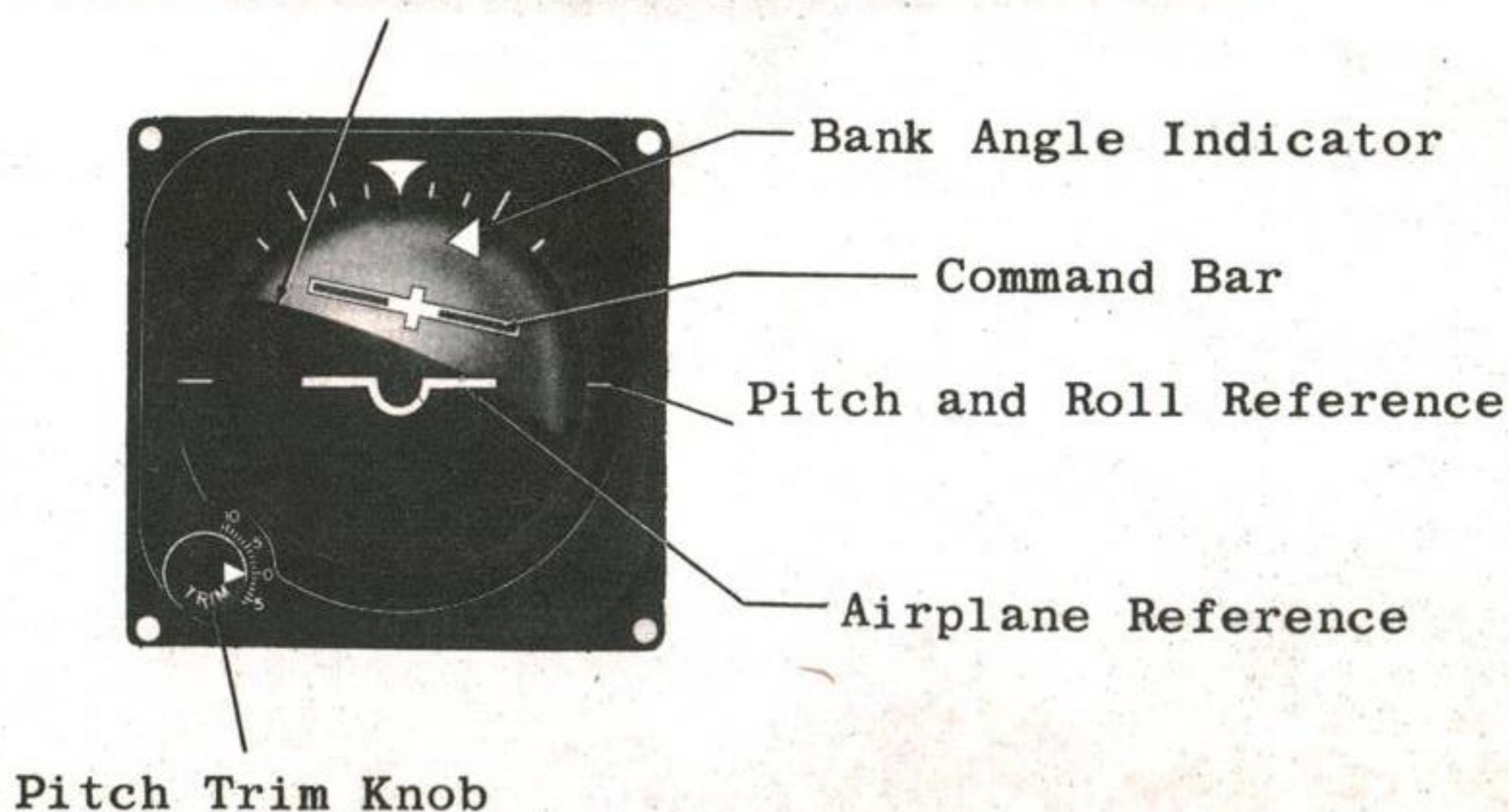


Figure 3 - Horizon Director Indicator

The aircraft is portrayed by a fixed white marker at the center of the indicator. Behind this aircraft reference, a moving sphere with 360° freedom pictures the horizon. The lower half of the sphere is black, the upper half light blue. A remote vertical gyro positions the sphere through a servo-mechanism, so that aircraft pitch and roll are accurately repeated.

Roll angles are read at the top of the instrument from the position of a rotating index against ten degree increments. Although the maximum roll angle reference is 30°, an additional 45° index may be added on the indicator face. Pitch angle is shown by the position of the aircraft reference with respect to the sphere horizon.

A TRIM knob, at the lower left of the indicator, allows the sphere to be positioned at level through a range of 11° nose up to 6° nose down flight attitude.

The command bar is a white-bordered, black line with a white cross in the center. The position of this bar, relative to the fixed aircraft reference, shows the pilot how much bank and attitude change is required to return to his selected flight. When the command bar is coincident with the aircraft reference, the aircraft is where it should be. If the aircraft is below the appropriate altitude, the command bar will move above the reference, indicating that the nose must pitch upwards; in other words, the pilot must take action that will return the command bar to the reference marker.

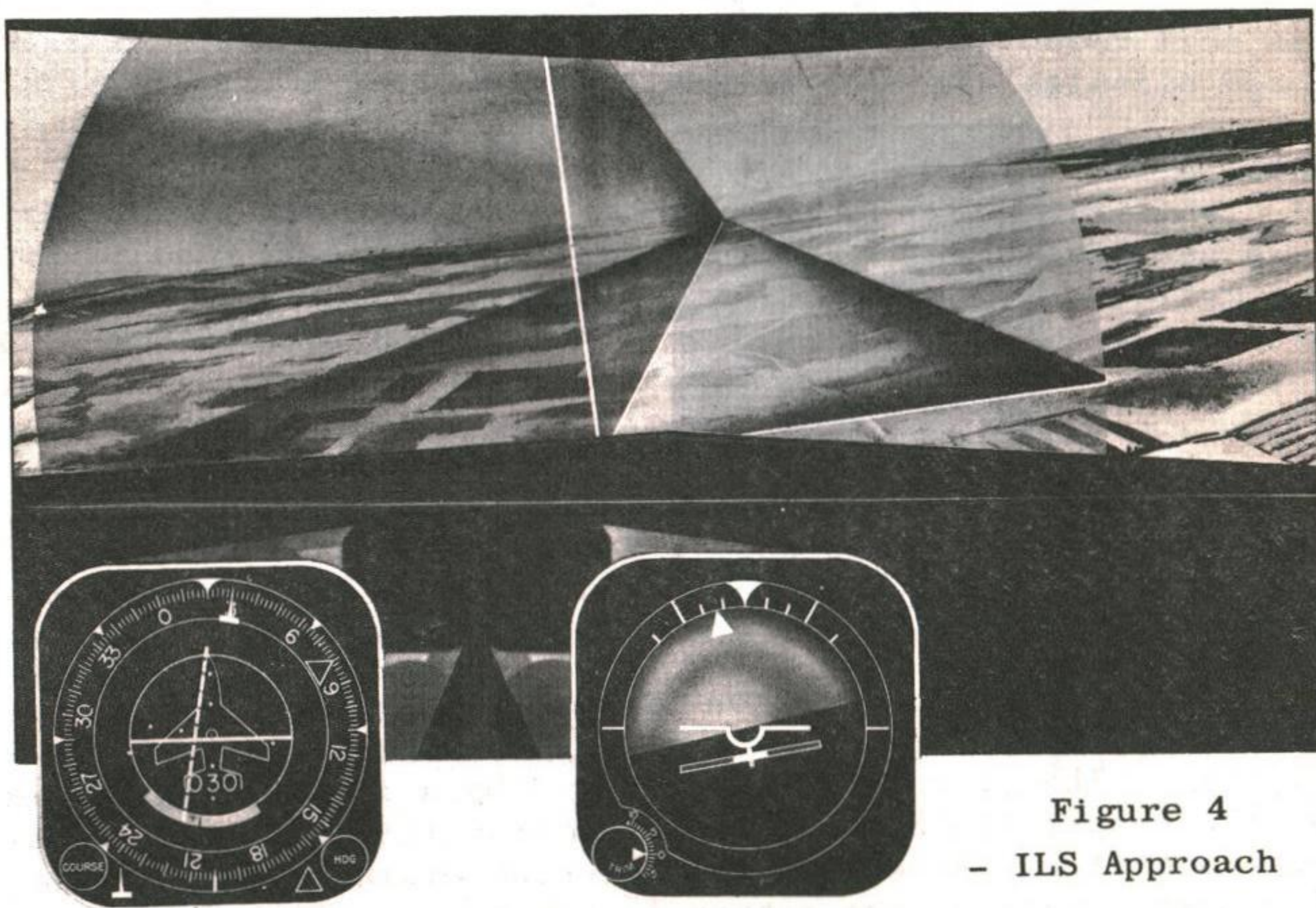


Figure 4
- ILS Approach

Figure 4 shows an aircraft with a 13° starboard roll, and zero pitch, intersecting the ILS glide path slightly starboard of the center line.

The course deviation bar indicates that the aircraft is slightly to the right of the localizer center line, and is closing with it at about a 10° angle. The glide slope bar places the aircraft slightly above the glide path. The command bar signifies to the pilot that he should roll port roughly 10° , and pitch the nose downward slightly. This

action would, of course, place the aircraft on the glide path, aligned with the localizer beam.

Flight Director Computer

The Flight Director Computer accepts information from the compass, vertical gyro, and radio aids, resolves it, and produces the pitch and roll signals to position the command bar. The intercept angle set up by the command bar to a desired course can be varied as required by the type of operation. Once the aircraft has intercepted the beam, the correct crab will quickly develop to maintain the aircraft on the center line in a crosswind. The computer also contains an output limiter which will confine roll commands to any desired maximum.

A special circuit in the computer produces non-linear sensitivity in the roll command display, so that the pilot can quickly recognize small displacements of the command bar near the zero position, and maintain more accurate flight.

As the pilot obeys the instructions of the command bar, the computer simultaneously drives it back to the zero position, which is coincident with the fixed aircraft reference. Thus the pilot is shown that he has carried out the proper manoeuvres, and the computer's task is momentarily completed.

Horizon Director Amplifier

Besides the power supply, the Horizon Director Amplifier contains amplifiers for the following signals: roll attitude and command, pitch attitude and command, and course deviation. The power supply required is 115V, single-phase, 400 cycle AC.

Vertical Gyro

When the Flight Director System is used in conjunction with the Bendix Automatic Flight Control System, a separate gyro is not required. Otherwise, an independent vertical gyro installation is necessary.

The separate gyro is electrically operated, and is constructed to have 360° freedom of rotation about the roll axis, with $\pm 85^\circ$ pitch allowance. Tumbling beyond the pitch limits is controlled.

When the system is switched on, the gyro is automatically erected by an electrical mechanism, so that it is ready for use in one minute.

Phase Adapter and Rate Cut-Off

This unit contains a phase adapter which supplies the appropriate power to the gyro, and a rate cut-off switch. This switch is operated by a gyro with a single plane of freedom. When the aircraft turns at a rate in excess of 15° per minute, the switch is closed, de-energizing the erection torquer in the bank axis, thereby reducing turning errors.

Installation

A block diagram of a dual cockpit installation is shown in Figure 5 below.

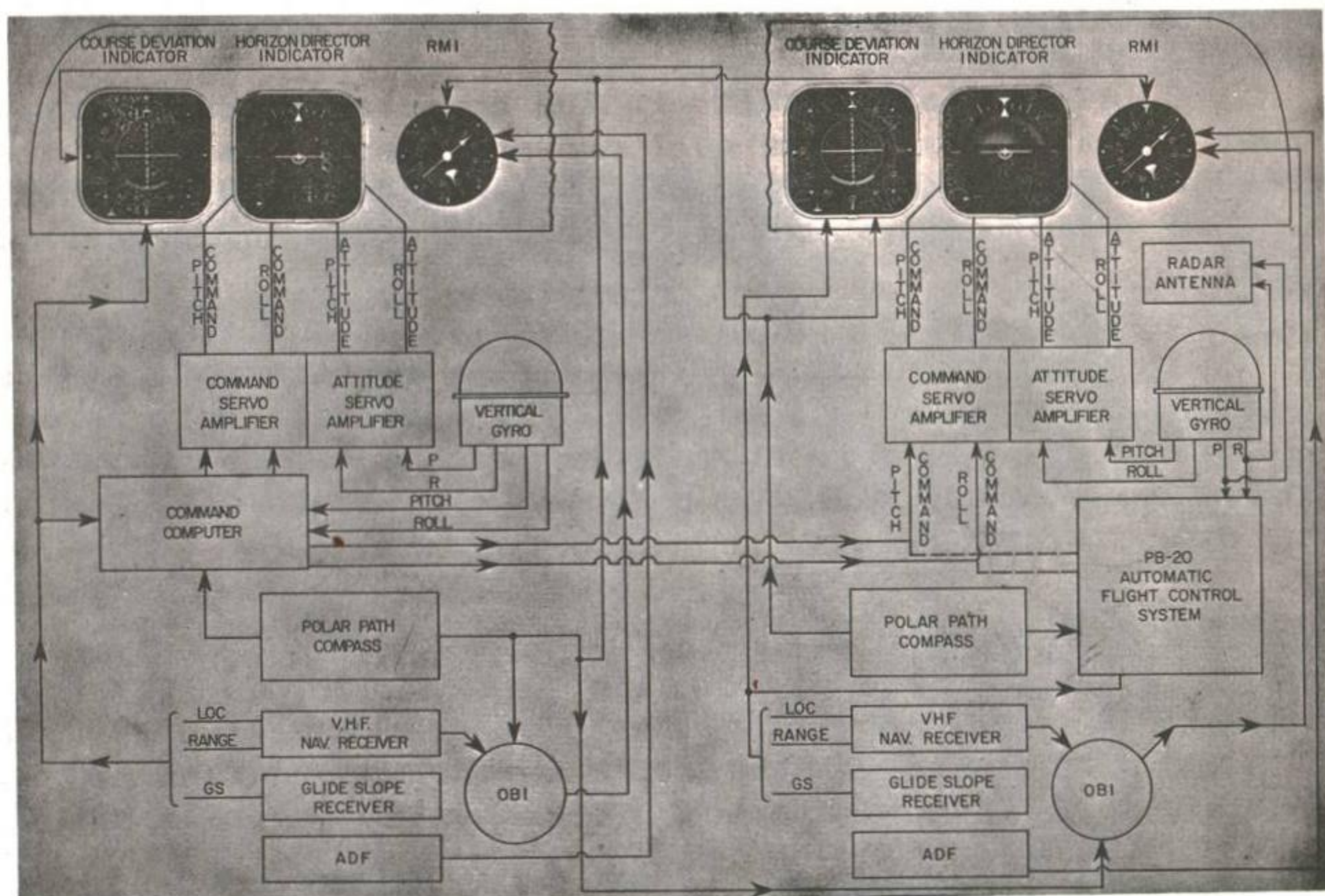


Figure 5 - Flight Director System

Conclusion

The Bendix Flight Director System is a decided improvement over the previous multi-instrument arrangements. It successfully combines into two instruments the standard indications of heading and attitude with ILS, position, and correction display. Once the flight programme has been selected, the pilot need only check that the vertical dotted bar is centered on one indicator, and that the command bar is aligned with the fixed reference on the other, to assure him of following his path. Malfunctions are made apparent immediately by flags, and limited use can be made of the system should the compass fail.

Gimbal



by Flight Lieutenant P.R.W. Webb
Air Force Headquarters

Recent improvements in the accuracy of directional gyroscopes has made significant some errors which were previously too small to be considered. One of these errors, and one on which very little information is readily available to squadron navigators, is gimbal error. This article is intended as an introduction to this subject and should be of particular interest to all observers, because correcting mechanisms for gimbal error are now being developed and installed on all modern compass systems.

GIMBAL ERROR

Introduction

A directional gyro, such as used in aircraft gyro compass systems, is separated from the aircraft structure by two gimbals. The inner gimbal, supporting the gyro rotor, lies in the horizontal plane. The outer, or azimuth, gimbal supports the inner gimbal and is normally at right angles to it (Figure 1). Aircraft heading is measured by a synchro which detects the relative movement between the instrument case (i.e. the aircraft) and the outer gimbal. Since the outer gimbal is orthogonal to the gyro axis in level flight, the detected heading will be the angle between the gyro axis and the aircraft fore and aft axis.

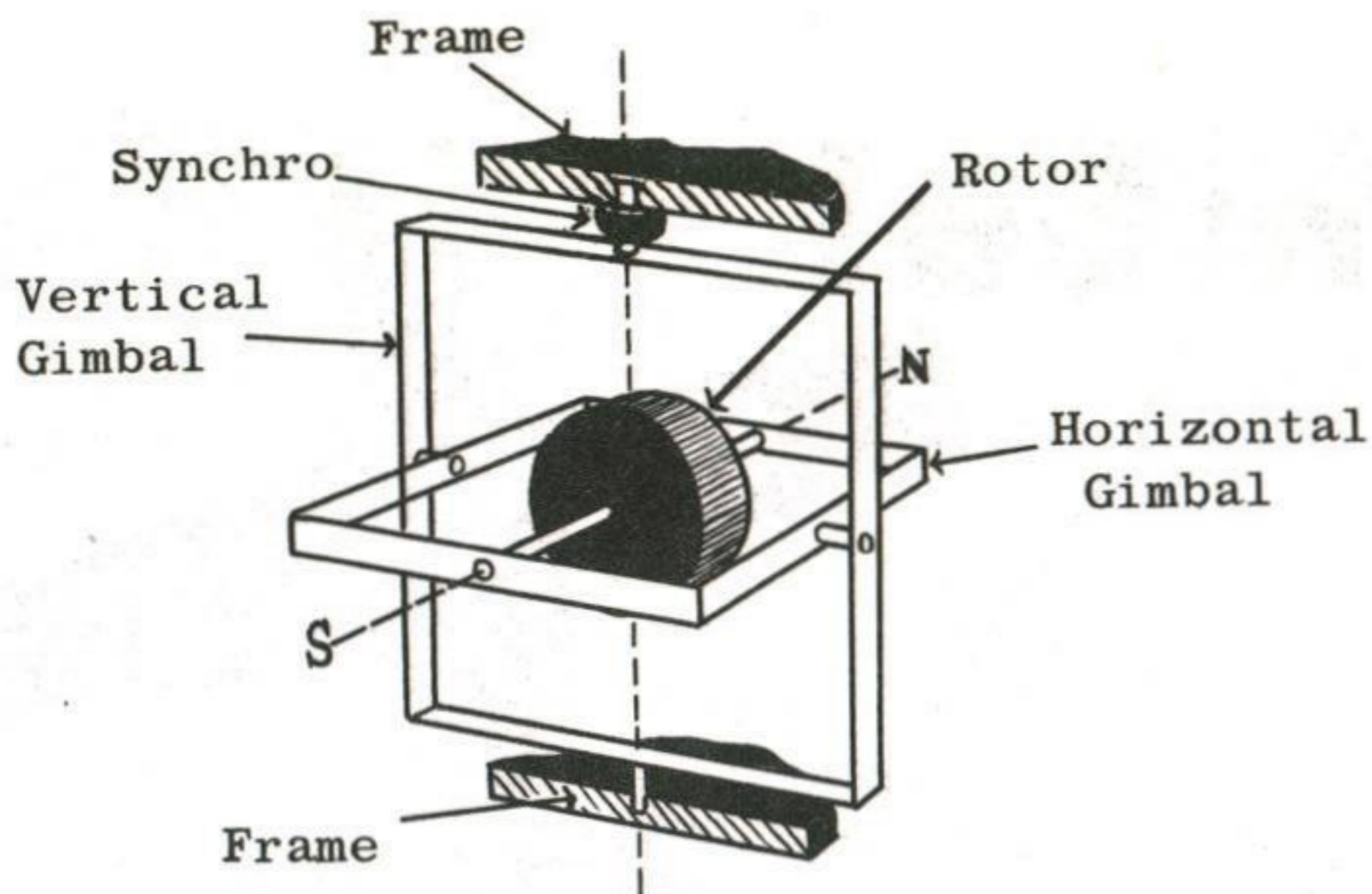


Figure 1

Gimbal Error

If the aircraft rolls or pitches, the indicated heading as read on the compass repeater, will differ from the correct aircraft heading unless the aircraft fore and aft axis happens to coincide with the gyro axis or to lie at right angles to it. The reason for this lies in the geometry of the gimbal system. The gimbal system is similar to a universal joint. A roll or pitch manoeuvre will cause the outer gimbal to move with respect to the gyro axis so that they are no longer in the same plane. Since correct heading is measured in the plane of the gyro axis, and aircraft yaw is measured in the plane of the outer gimbal, when these two frames of reference no longer coincide an error in measured heading will result. This is termed gimbal error (Figure 2).

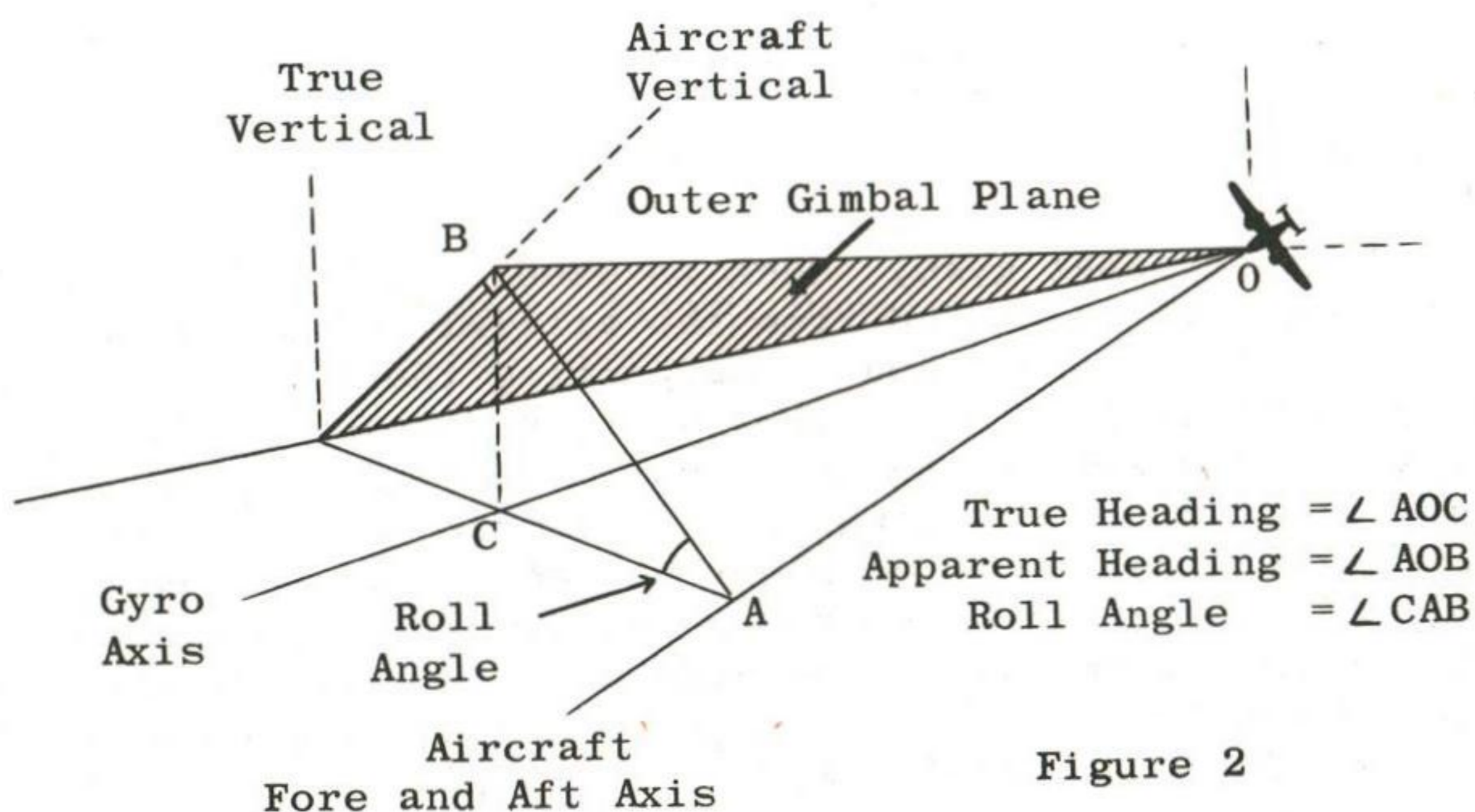


Figure 2

The relation between the true heading and the indicated heading is given by:

$$\tan(\text{apparent heading}) = \tan(\text{true heading}) \cos(\text{roll angle})$$

It should be noted that the gimbal error will appear as soon as a roll is commenced, even before the aircraft has begun to turn. If we were to take the trouble to work out the error for various headings and roll angles we would obtain a curve similar to that of Figure 3.

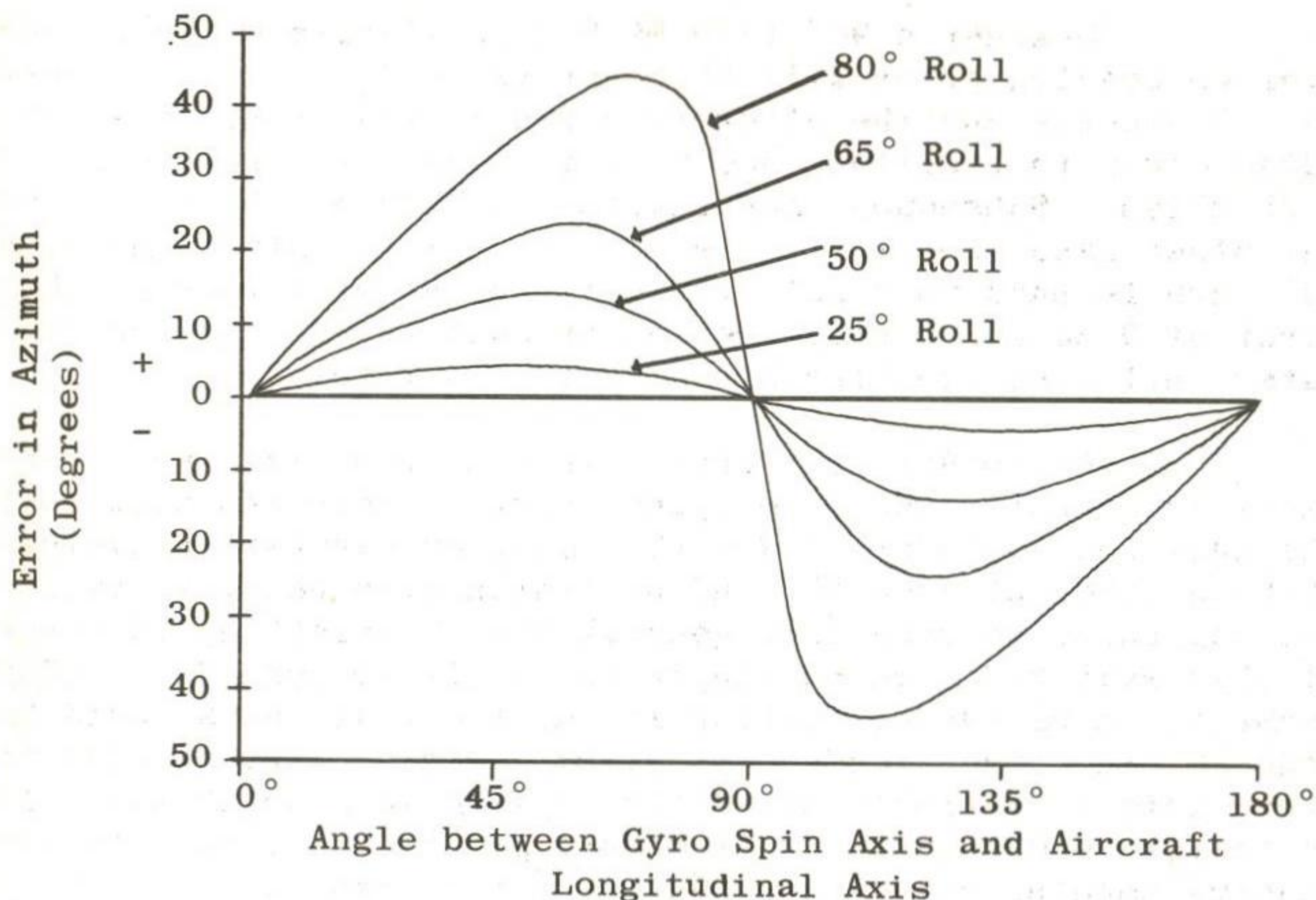


Fig 3 - Curve of Error

It is evident that for large roll angles quite an appreciable heading error will appear. Similar curves can be obtained for the case where the aircraft pitches without rolling. In this case the relationship is given by:

$$\tan(\text{true heading}) = \tan(\text{apparent heading}) \cos(\text{pitch angle})$$

A proof of the general formula where pitch and roll are both present is given in the Appendix. This would plot into a complex series of curves showing large errors in heading for particular combinations of roll and pitch.

Practical Effects of Gimbal Error

Apart from the false indication of heading which appears there is a more important effect. The average value of heading error produced during a turn will be integrated into navigation computers and GPI equipment to produce an error in computed position. If the turn is exactly 180° or 360° the error will be cancelled owing to the change in sign for each 90° quadrant. For any 90° or 270° turns a residual error will remain in the navigation computer even though the heading error disappears when the aircraft is level again.

Consider a 90° turn with a roll angle of 60° . The average heading error will be about 12° . If the turn lasts for 15 seconds and the aircraft speed is 300 knots, the computed error in position due to gimbal effect will be about 0.25 miles. Subsequent manoeuvres may reduce this error; on the other hand they may increase it. If in this example, a 90° turn is made to regain the original heading then another error of 0.25 miles would be fed through the navigation computer, bringing the bias error up to 0.5 miles.

This order of error in position may seem very small and hardly worth worrying about. This was certainly the case until recently. Now that doppler navigation systems of high inherent accuracy, and precision gyro heading systems are beginning to come into general use in aviation, an error of this magnitude is no longer too small to consider. For example, maritime navigation in the tactical area would be reduced in effectiveness if gimbal errors were allowed to creep into a tactical navigation system such as ANTAC. It is therefore desirable to eliminate gimbal error as a factor causing heading degradation during manoeuvres.

Solutions to the Problem

The gyro manufacturers are well aware of the problem, and three major approaches to its solution have appeared. These are:

- > Roll stabilization of the gyro.
- > Stable Platforms
- > Gimbal error correctors

It is not proposed to go into detail on these methods, since any one of them would alone demand a complete article. Brief mention only will be made.

Since the gimbal error results from the tilting of the outer, or azimuth, gimbal with respect to the gyro axis, one method of eliminating the error would be to maintain the outer gimbal vertical at all times. This is achieved in roll stabilized systems by using an additional gimbal to support the basic directional gyro (Figure 4). A servo motor, slaved to the roll output of a vertical gyro, positions this gimbal to maintain the azimuth axis of the directional gyro exactly parallel to the apparent local vertical through 360° roll of the aircraft. The detected heading angle will then be the correct heading as measured in the horizontal plane of the gyro.

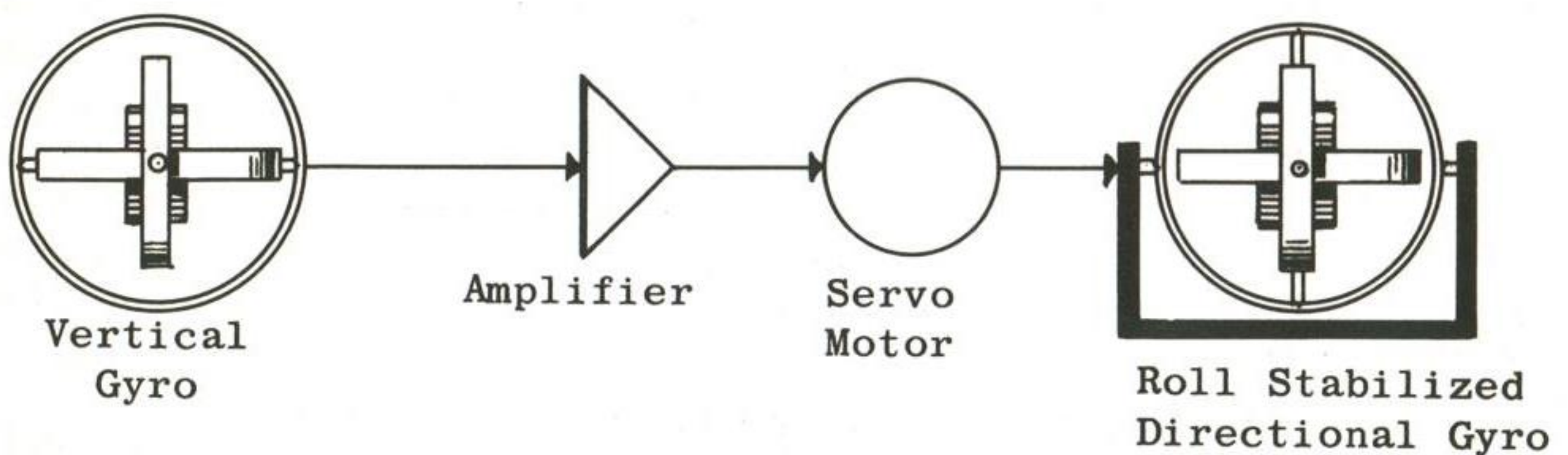


Figure 4 - Roll Stabilization

A more elaborate version of this principle is to use a stable platform.* The platform is maintained fixed in space by two, or sometimes three stabilizing gyros mounted with their axes mutually perpendicular. The platform is isolated from aircraft motion by three gimbal rings if 360° freedom in roll is required. Four gimbal rings are needed if full freedom is required in pitch as well. Heading angle is always measured correctly between the platform axis and its azimuth gimbal, since these always remain orthogonal. Stable platforms were developed to provide central gyro reference systems of high accuracy as a source for measuring all angular movements of the aircraft. The fact that they also overcome gimbal errors is an additional dividend.

A third approach to the problem is to correct the false heading information from an unstabilized directional gyro by using a computing network. From the gimbal error formula it can be seen that if the values of false heading and roll angle are known, then the value of correct heading is always obtained. By coupling roll data from a vertical

* "The Stable Platform". RCAF OBSERVER Apr 58.

gyro output, to a suitable servo-driven computing circuit, the correct heading can be computed and transmitted to the navigation system (Figure 5). This method has been developed in Canada and has the great advantage that complex stabilization of the gyro is not required. The correction computer is in the form of a "black box" which can be used with any existing compass system.

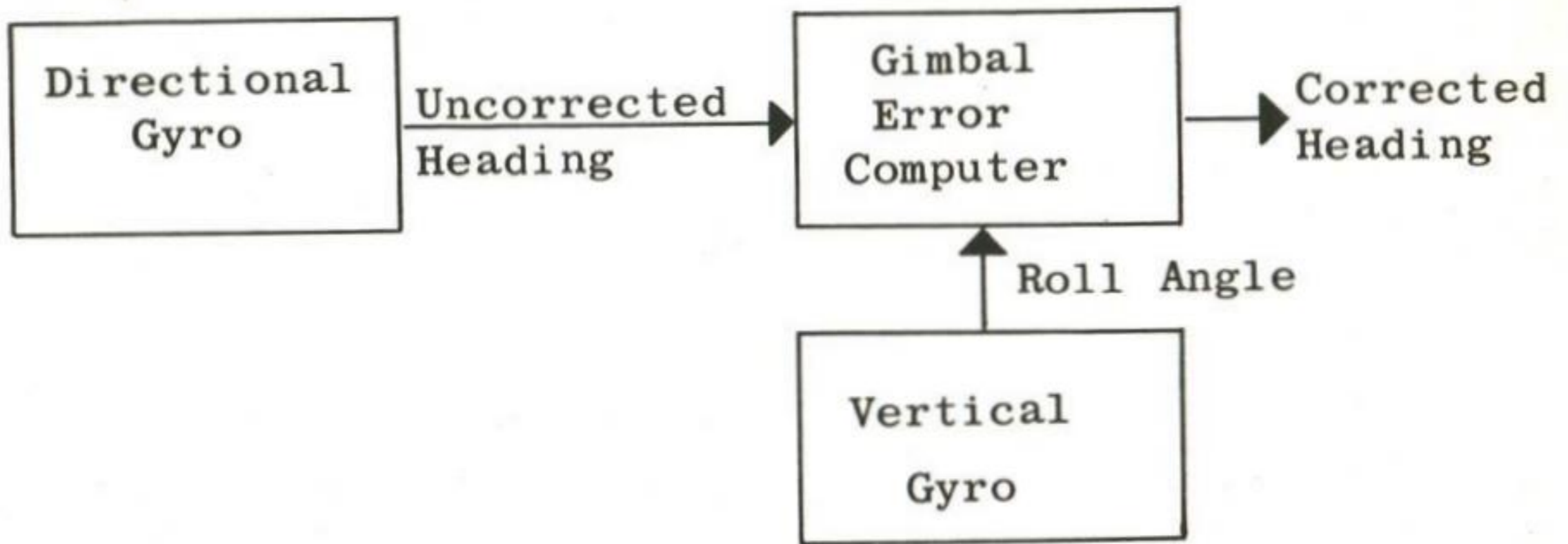


Figure 5

Conclusion

This article has endeavoured to give a short and simplified explanation of the cause and effects of gimbal error. The gimbal error problem has been of more concern to system designers than to navigators until very recently. Now, however, we are on the threshold of an era of more precise navigation systems, where errors formerly too small to worry about must be considered, and it is felt that this subject has a place in the pages of the OBSERVER.

APPENDIX

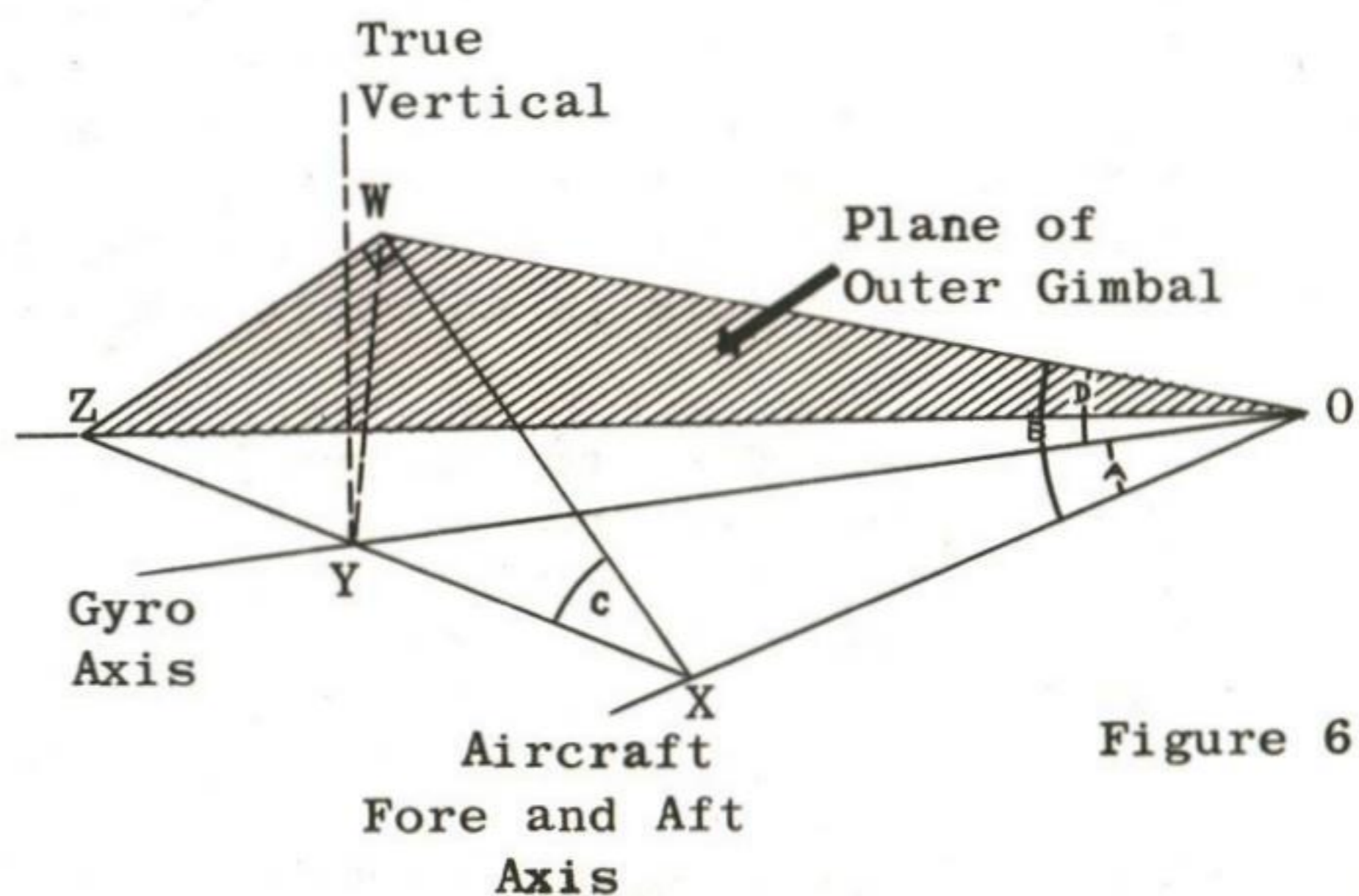


Figure 6

- A = True Heading
- B = Apparent Heading
- C = Roll Angle
- D = Pitch Angle

The diagram shows the conditions existing when an aircraft has simultaneous roll and pitch attitudes. The plane of the outer gyro gimbal is shaded. This gimbal plane is tilted from the gyro axis plane by an amount equal to roll angle. In addition the outer gimbal vertical differs from the true vertical by the amount of pitch angle. Therefore we have:

$$\begin{aligned} \tan A &= \frac{XY}{YO} \\ &= \frac{XZ - YZ}{YO} \\ &= \frac{XW}{\cos C} \cdot \frac{\cos D}{OW} - \frac{YZ}{YW} \cdot \frac{YW}{YO} \\ &\quad (\text{XWZ, YWO, are right angles}) \\ &= \tan B \cos D - \tan C \sin D \\ &\quad (\text{XWO, WYZ, are right angles}) \end{aligned}$$

If angles are measured from XO as negative in a clockwise direction and positive in an anti-clockwise direction this gives:

$$\tan(-A) = \frac{\tan(-B) \cos D}{\cos C} - \tan C \sin D$$

$$\tan A = \frac{\tan B \cos D}{\cos C} + \tan C \sin D$$

If pitch is zero the expression becomes

$$\tan A = \frac{\tan B}{\cos C}$$

$$\therefore \tan B = \tan A \cos C$$

If roll is zero the expression becomes

$$\tan A = \tan B \cos D$$



Dear Sir:

Reference the "Professional Military Navigator" article by Flight Lieutenant Connolly in your April issue of the RCAF OBSERVER, I agree wholeheartedly with F/L Connolly's proposition and his two supporting arguments, and I would add that eventually the Observers themselves would benefit careerwise through this added motivation. However, I cannot but disagree with the USAF criteria being applied to the RCAF at this time.

The service time as a rated Observer should be four years. This would not take away from the Short Service Observer the tangible goal aspect, and would add to his motivation for putting more effort into becoming a suitable candidate for a Permanent Commission. Besides, after seven years, the man of Senior Navigator calibre likely has been rewarded by promotion.

The flying time should be cut down proportionally to somewhere between 1250 hours for the Long Range Observer/Nav and to 750 hours for the Observer/AI, or a total of 1500 hours for mixed flying experience. Surely one becomes a professional, if one will ever become so, after getting this amount of flying experience; otherwise it could be said that the last war did not produce many professionals for a long time.

That a comprehensive written exam be a requirement is apparent, but if it is in his speciality, then you no longer discriminate between "one navigation compartment" knowledge and well-rounded experience. The Senior Observer should have a broad knowledge of his whole field in theory at least, besides being fully cognisant of a particular speciality.

The supervised flight check is in my opinion, a debatable point. To balance the experience of four years in the field and hundreds of sorties, trip searches, or what have you, against one check trip is indeed debatable. To me the combined recommendation of one's OC and Flight Commander or Nav Leader is much more realistic and would not favor the "Expert Log Keeper".

The stipulation that a candidate should be engaged in flying duties at the time should be modified in order that the exigencies of the Service, such as "ground tours", are not made to appear harsher than necessary. Why not consider those who have left flying duties for less than a year, and have flown since then an average of 36 hours per quarter? The extra 11 hours would prove that they are not "In for the money only".

It may seem that I have favoured the "Proletariat" in pulling down the standards of the Senior Navigator elite as proposed by F/L Connolly, but would it not be much more beneficial to the RCAF, and still be rewarding to the individuals, to have ten times the number of people striving to attain a goal more within their reach, and from which there would likely emerge numerous truly professional military observers?

L.Noel de Tilly F/L

Observer Leader
423 AW (F) Squadron
2 (F) Wing, RCAF

Dear Sir:

I refer to the article "Lets Recognize the Professional Military Navigator" published in your April issue.

The plan as put forth by F/L Connolly seems a plausible method of recognizing achievements of long range transport navigators. However, the criteria used by the USAF will ignore many professional AI navigators in the RCAF. If these professionals are to be given recognition, I propose that the flying time and service time required for a senior navigator in the AI list be reduced by at least one half of that required by long range navigators. This proposal, I believe, is a valid one, as the average yearly flying time for an AI navigator on a CF-100 Squadron is much less than that accumulated by a long range navigator on a transport squadron. Yet the experienced man in the back seat of a CF-100 is just as much a professional as a senior navigator of a North Star or C-119 aircraft.

The plan, with a modification as suggested, seems valid.

L.A. Fry F/L

423 AW(f) Squadron
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PREVIEW
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The RCAF
OBSERVER

PRINCIPLES OF INERTIAL GUIDANCE PART II



THE RCAF MERIDIAN CONVERGENCY COMPUTER



RADIO WEB



LEAR INTEGRATED FLIGHT SYSTEM



SPECIALIST NAVIGATOR TRAINING



SINGLE SIDEBAND



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11 SPECN COURSE PHOTO



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