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CONTENTS ISSUE 28

FRONT AND BACK COVERS The Seahawks of VP-23 trace their history back more than a half century to the year 1922 and scouting squadron VS-1S. Through the 1920's the squadron was successively redesignated VT-3 and VT-9S, and in 1930 it received its first patrol squadron designation – VP-10S. Three years later the squadron became a base force rather than a scouting force, was designated VP-10F, and made its home port NAS Pearl Harbor. Shortly thereafter the squadron made aviation history, conducting the first non-stop, formation flight from San Francisco to the Hawaiian Islands. In 1937 the squadron dropped the "F" from its designation and, with the fleet wide redesignations of 1939 and 1941 the squadron became first VP-25 and then VP-23.

During the attack on Pearl Harbor in 1941 eight of VP-23's twelve Catalina aircraft were destroyed. The squadron's four remaining PBY's were the only Navy patrol aircraft to become airborne that morning when the United States entered World War II. In the months that followed, VP-23 was refitted and staged operations from Johnston and Palmyra Islands, took part in raids on the Gilbert and Marshall Islands, and then deployed in mid-1942 to take part in what was to be the Battle of Midway. Within days after the squadron's arrival at Midway a PATRON 23 Catalina pinpointed the enemy fleet for the American forces.

As the war moved across the Pacific, VP-23 continued island hopping. They participated in the U.S. invasion of Guadalcanal and flew open ocean patrols and rescue, supply, and convoy escort missions. During one of these latter missions one of the squadron's aircraft attacked and sank an enemy sub.

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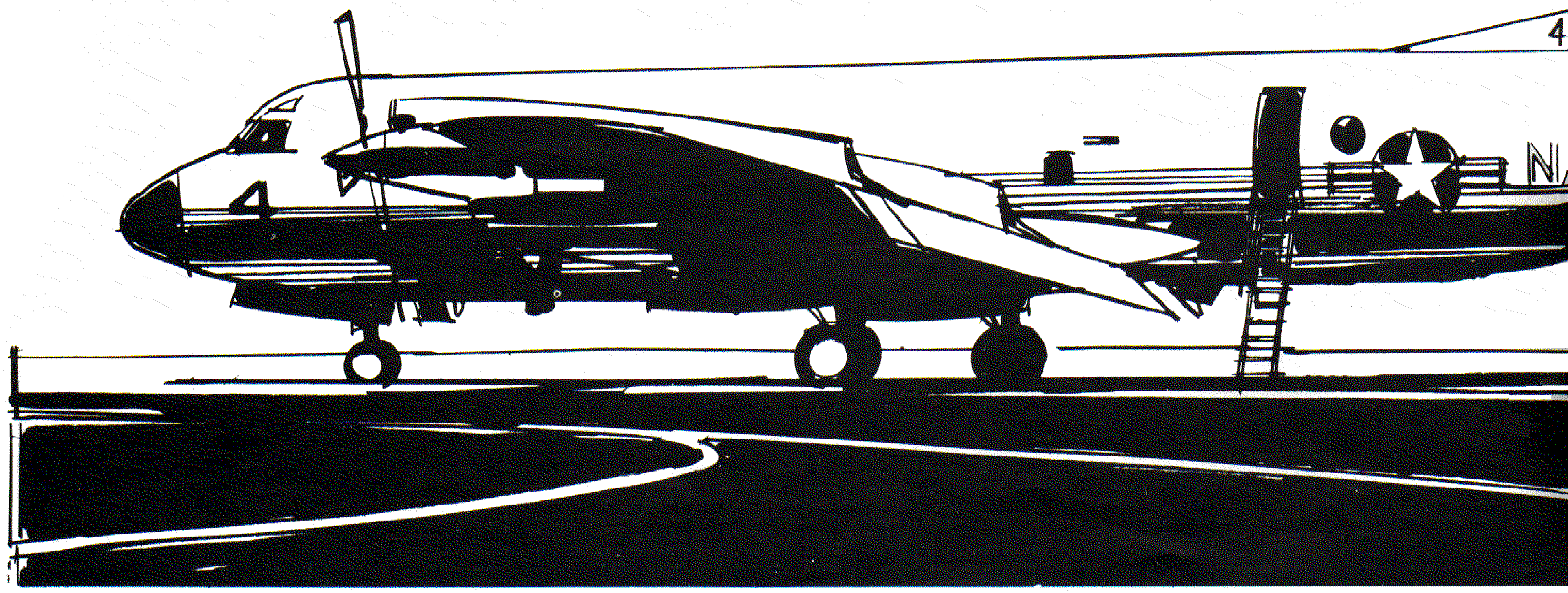

Early in 1944, Patrol Squadron 23 returned stateside via Hawaii for a well deserved rest. The squadron was then disbanded, only to be re-established shortly thereafter with new PBY-5A's as a "Black Cat" squadron. In June 1944 they were back into the thick of the Pacific war operating from Midway, Hawaii, and Eniwetok. Five months later the squadron was redesignated VPB-23, and continued its courageous efforts throughout the remainder of the conflict.

At war's end VPB-23 returned to the United States and was decomissioned in January 1946, only to be recomissioned the following May as VPW-3. Equipped with new PB4Y Privateer aircraft and based at Miami, the squadron flew storm-tracking missions during the hurricane season and ASW missions during the rest of the year. Two years later the squadron had a fling at show biz, providing technical assistance for the movie "Slattery's Hurricane." As the 1948 hurricane season blew to a close, the squadron was redesignated VP-23. For its all-around excellence during fiscal year 1949, VP-23 was awarded the Chief of Naval Operations Battle Efficiency Pennant.

In 1952, PATRON 23 moved to NAS Brunswick and transitioned to the P2V Neptune. Throughout the 1950's the squadron made numerous deployments to sites in the North Atlantic, Mediterranean, and Caribbean.

Highlights of squadron activities during the early and mid '60s included participating twice in searches for pirated ships, assisting in the blockade of Cuba during the missile crisis of 1962, providing lifeguard service for CDR Shirra's Sigma 7 space shot, and searching for the ill-fated USS Thresher. In 1965, Patrol Squadron 23 participated in UNITAS VI, a combined North and South American ASW exercise. During these years VP-23's outstanding performance did not go unrecognized. The squadron was awarded 3 consecutive Battle Readiness Excellence pennants, a feat that was unprecedented and is still unequalled. In 1966 the squadron was awarded the Arnold J. Isbell Trophy for ASW excellence.

The squadron continued operations for the next two years with deployments to Iceland, Spain, Norway, Scotland, Ireland, Denmark, and Sicily. When VP-23 returned from its 1968 Sigonella deployment it began to decommission, but the Secretary of Defense gave the Seahawks a last-minute reprieve. Back in business, the squadron rebuilt itself, then deployed again to Sicily. Upon their return, VP-23 transitioned to the P-3B Orion, and in January 1970 they retired the last P-2 Neptune from the active Navy. Another deployment took the squadron to Spain and the Azores, and for their efforts they were awarded the Meritorious Unit Commendation. Soon thereafter the squadron converted to the P-3B(D) version of the Orion.

During the past two years the Seahawks have continued to meet their commitments over the North Atlantic and the Mediterranean. In the fall of 1972 they sported the highest squadron readiness in the Atlantic Fleet. Today PATRON 23 is participating in UNITAS XIV, the annual joint U.S./South American Naval exercise, exemplifying their motto "Volens et Potens" – Willing and Able.

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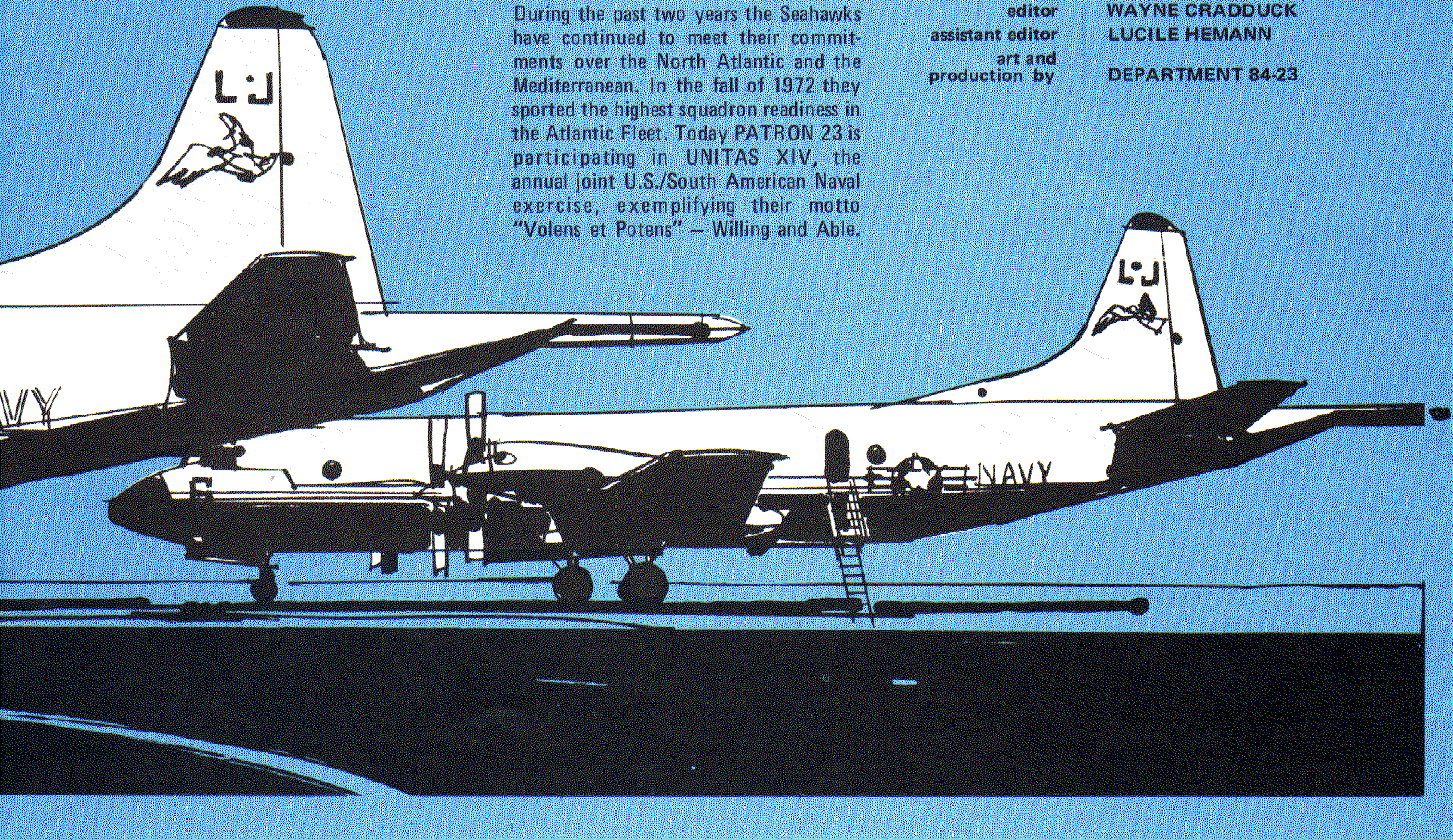

Magnetic Anomaly Detection

The Total System in Relation to Compensation

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INTRODUCTION

Since the first magnetic anomaly detection (MAD) set was introduced 30 years ago significant improvements have been made to the equipment. The latest advances in the MAD field are incorporated in the AN/ASQ-81 Magnetic Detecting System installed on the P-3C airplane. In addition, a semi-automatic active method of minimizing the magnetic influence of the aircraft on the ASQ-81 system was introduced with the installation of the AN/ASA-65A Magnetic Compensator Group in the P-3C.

The AN/ASA-65 Magnetic Compensator Group, also known as the 9-Term Compensator (9 TC), provides optimum compensation to reduce magnetic interference at the detector sensor of the MAD set. Interference caused by aircraft-generated magnetic fields during flight is minimized as the compensator semi-automatically establishes a magnetic field, the nine components (terms) of which reduce corresponding components of the interfering field to an acceptable minimum. The purpose of the 9 TC, then, is to improve the effectiveness of the magnetic anomaly detector by compensating for the influence of the airplane's fixed magnetic fields and of the magnetic fields generated or changed during maneuvers.

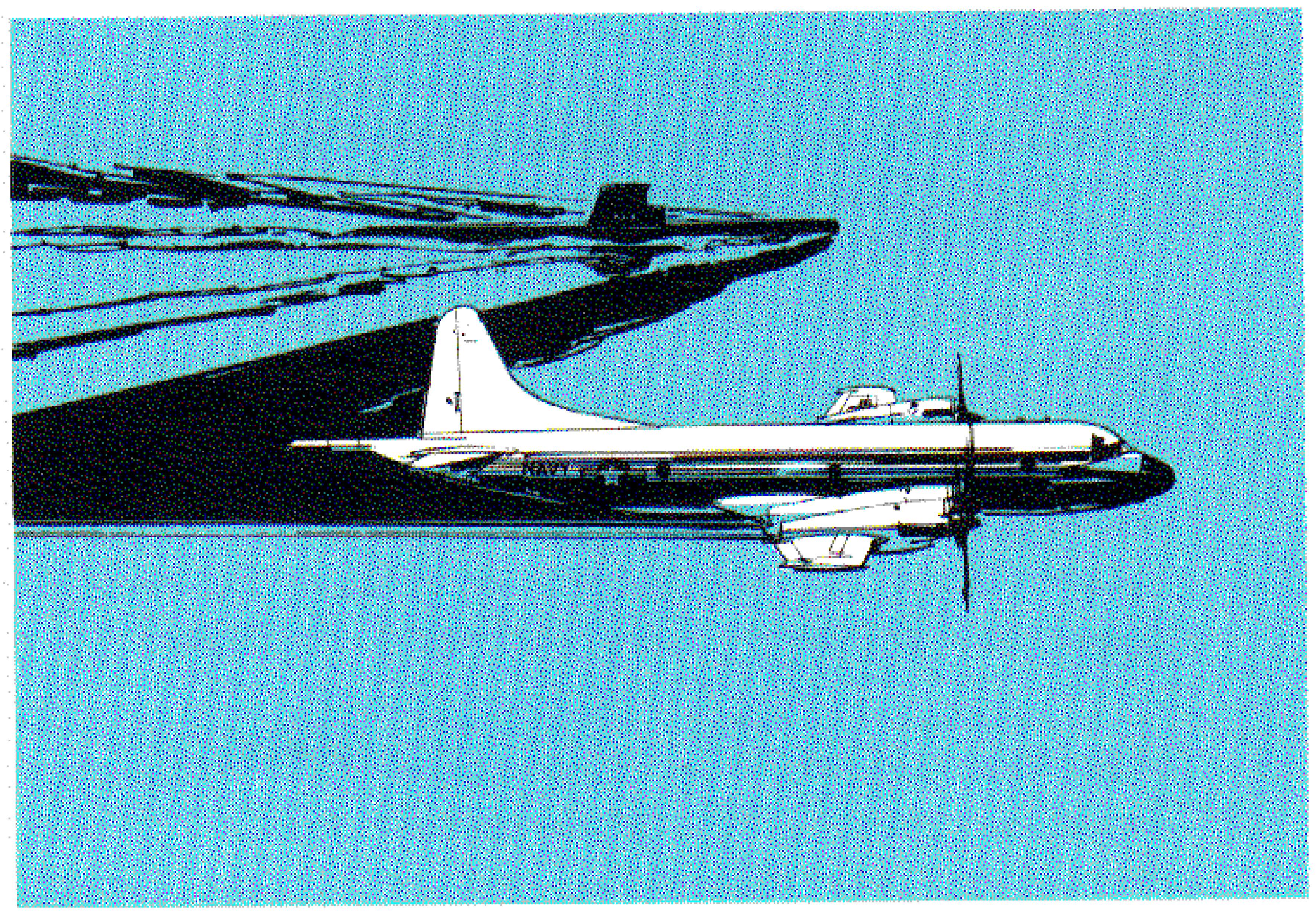
The 9 TC is semi-automatic in that it can be preset to compensate for an individual aircraft's magnetic characteristics. The 9 TC then generates proper compensating magnetic fields until a change in the aircraft magnetic signature necessitates recompensation.

This article emphasizes fundamentals instead of a procedural approach, and in so doing may answer some of the questions often asked of our Field Service Representatives. Although most of the discussions pertain to the P-3C and its equipments, the basic concepts of magnetic compensation apply to any aircraft equipped with MAD gear. Space limitations made it impossible to discuss all phases of MAD systems, and discussion of tactics has been omitted due to the classified nature of the material.

MAGNETIC ENVIRONMENT

The magnetic environment in which the MAD system operates affects system performance. The influences of these environmental factors must be compensated for if the system is to function properly. This section discusses environmental magnetic fields and their sources.

THE EARTH'S MAGNETIC FIELD The earth's magnetic field is produced by a dynamo effect in the earth core, but it can be approximated by an imaginary short bar magnet located at the center of the



earth. The polarity and general location of the earth's magnetic poles are opposite that of the earth's geographic poles, thus the magnetic South pole is located near the geographic North pole, and vice versa.

The direction of the earth's magnetic field is along the imaginary lines of force connecting the two poles of the earth's field. By convention, lines of force emerge from the South magnetic pole and enter the North magnetic pole. Deviation of the magnetic field lines from the geographic North-South direction is called magnetic declination (sometimes called magnetic variation).

Dip Angle The direction of the magnetic field with reference to the horizon varies with one's position on the earth. For example, the field is perpendicular to the earth's surface at the magnetic poles and horizontal to the earth's surface at the magnetic equator. The angle at which the earth's magnetic field intercepts the earth's surface in the vertical North-South plane is called the magnetic dip angle or magnetic inclination. For this article, only the dip angle is of importance.

In a manner analogous to determining the earth's geographic latitude, dip angles are used to determine magnetic latitudes. The location with zero dip angle is known as the magnetic equator. The dip angles are labeled North and South as are geographic position. Figure 1 is a chart of dip angles.

Field Intensity In geomagnetism the magnetic field is expressed in terms of oersteds, gauss, or gammas* (one oersted is equal to 100,000 gammas). The earth's magnetic field intensity is a function of geographical location and varies from approximately 25,000 gammas (0.25 oersted) at the magnetic equator to 68,000 gammas (0.68 oersted) at The magnetic poles. (See Figure 2.)

Horizontal and Vertical Gradients For every mile of travel from the magnetic pole toward the magnetic equator, the total field intensity decreases by an average of approximately eight gammas. This change in total field intensity versus a change in position (nautical miles) is denoted as the horizontal gradient.

The vertical gradient of the earth's magnetic field intensity can be calculated first at a position one nautical mile high and then on the surface. At the magnetic poles the field intensity is about 60 gammas less at one mile altitude than on the surface as compared to a difference of about 22 gammas for similar calculations at the magnetic equator; i.e., the vertical gradient will be one gamma per hundred feet at the poles and nearly 0.4 gammas per hundred feet at the magnetic equator.

Field Components Having defined the earth's field direction and its magnitude, we have defined a vector (or arrow) which can be resolved into horizontal and vertical components. The horizontal component is a vector lying in the horizontal plane pointing at the North magnetic pole (just like a wet compass). The horizontal component is greatest at the magnetic equator and zero at the magnetic poles. The vertical component is a vector lying parallel to the earth's vertical North-South plane, pointing down in the Northern magnetic hemisphere and pointing upward in the Southern magnetic hemisphere.

Resolution of the earth's magnetic field into horizontal and vertical vectors will be useful when discussing magnetic field compensation later in the article.

AIRCRAFT- AND EQUIPMENT-GENERATED MAGNETIC FIELDS As magnetic sensor sensitivity is improved, the design and maintenance for prevention of noise sources become more critical. This section includes discussions on magnetic fields (noises) caused by nature, some internal magnetic sources, and aircraft-maneuver-generated magnetic fields.

MAD Sensor Installation The MAD sensor is extremely sensitive to magnetic effects. Consequently, considerable effort is made to isolate the sensor from nearby ferrous parts that introduce additional magnetic fields which the compensator is not programmed to minimize.

In the P-3C, the AN/ASQ-81 sensor is installed at the end of the MAD boom, which places the nearest aircraft part five inches from the sensor. The

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**Recent scientific measurement standards designate the gamma as one nanotesla, nT (10^{-9} tesla), however, this discussion will retain the designation of gamma.*

Figure 1. Magnetic Inclination or Dip Angles for the Northern and Southern Hemispheres

Figure 2. Earth's Total Field Intensity for the Northern and Southern Hemispheres

boom is formed from honey-combed plastic material overlaid with layers of fiberglass. Most parts in the boom are military-specified and have a 100-percent inspection for magnetic cleanliness.

The MAD boom is divided into four magnetic zones as illustrated in Figure 3. Zone 1 has the greatest magnetic cleanliness, and Zone 4 the least. The following color code is used on parts which have been inspected for magnetic cleanliness to ensure that they are used in the proper zone:

Zone 1	Purple
Zone 2	Orange
Zone 3	White
Zone 4	Brown

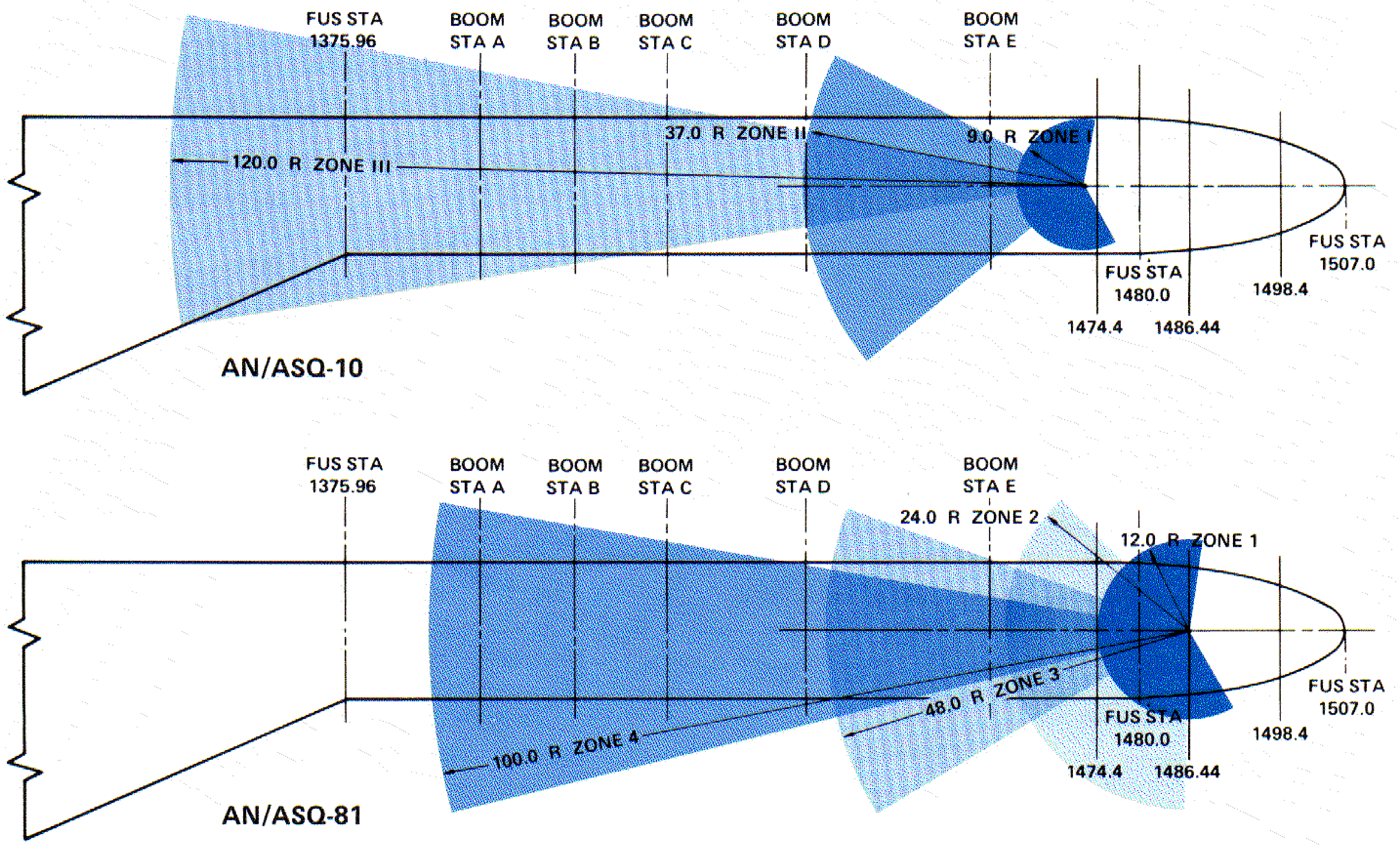
A part coded for use in a lower zone number can also be employed in a higher zone number. When working on the boom, remember to use only clean (not oily or greasy) non-magnetic tools. Be certain to observe the instructions on the aircraft decals located on the boom. If a part is lost, it must be replaced by a Lockheed Specification part or one that is certified by the Local Naval Air Rework Facility (NARF) in accordance with the aircraft maintenance manual.

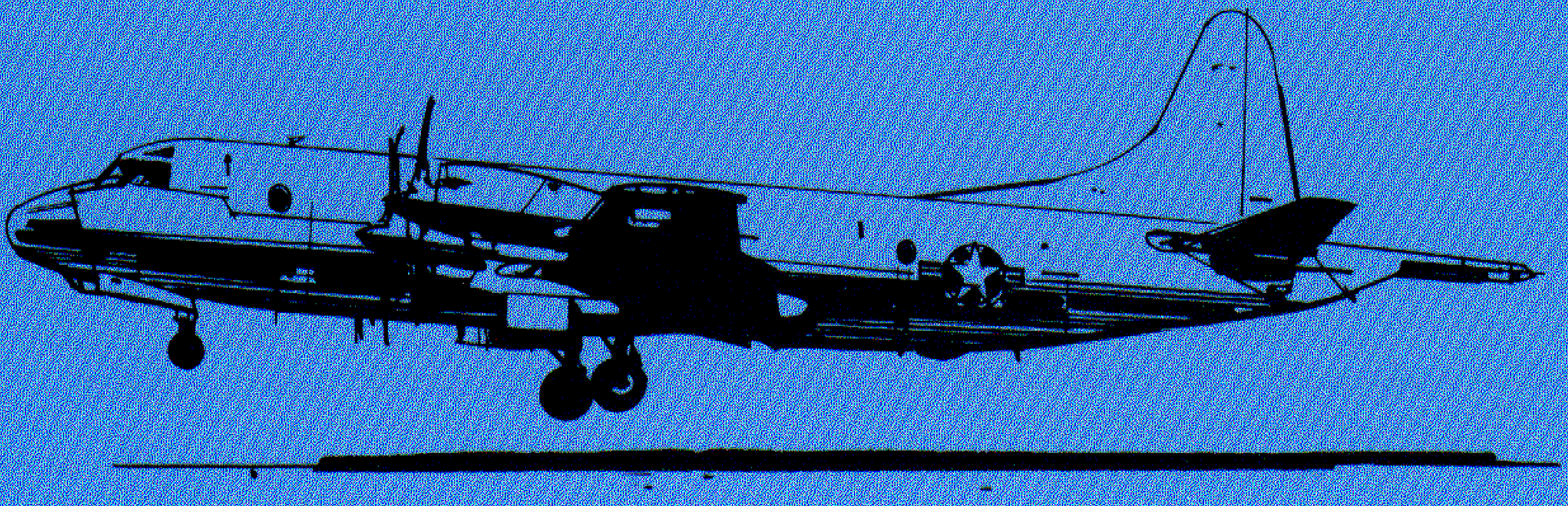
Large Ferrous Parts Magnetic fields introduced by large ferrous parts (such as landing gear and other large structural parts) are easily neutralized by the compensator since they are located at a considerable distance from the MAD sensor.

Aircraft Moving Parts Certain aircraft parts and assemblies such as control boost packages, control cables, and moving aircraft control surfaces can cause magnetic noise. It is difficult to compensate for these noises since compensation is based on a rigid airframe coordinate system that does not consider moving parts.

The elevator and boost packages for the P-3C are located aft of the Fuselage Station (F.S.) 1117 pressure bulkhead. These mechanisms have rather large moving ferrous parts which are degaussed. Aircraft equipped with the AN/ASQ-81 have boost packages that are manufactured in accordance to a

Figure 3. Comparison of ASQ-10 and ASQ-81 MAD Zones





more severe demagnetization specification* than were boost packages on earlier aircraft. In order to identify these boost packages from previously delivered ones, they are decaled with a statement referring to the specification. For the AN/ASQ-81 equipped P-3C, the empennage control cables that pass through the F.S. 1117 pressure bulkhead and the autopilot disconnect cable are made of nonmagnetic material per MIL-C-18735. The magnetic effect of the rudder and elevator posts is assumed to be insignificant.

The aft AN/APS-115 radar antenna has a large magnetic moment and is located relatively close to the MAD sensor. Since its rotation rate (6 rpm) is well within the bandpass of the MAD filter, antenna movement creates a large undesirable magnetic field which is easily detectable by the MAD sensor. After considering degaussing the antenna, it was decided to park the antenna during MAD operation at 0° relative bearing and 0° elevation angle since the radar has little use in a MAD tracking pattern. The antenna is parked by placing the aft radar system in the Standby Mode of operation. If unexplained MAD noise occurs, this antenna should be checked to make certain it is parked correctly.

The magnetic cleanliness of an aircraft can be tested by parking the aircraft on a North magnetic heading in a magnetically quiet area. A full throw of all the controls simultaneously (i.e., ailerons, elevators, and rudder) should not generate a noise greater than 0.1 gamma at the MAD sensor. This can be checked by observing the MAD recorder. The MAD Maneuver Program (Signal Generator Distributor) of the autopilot can be employed on the ground to generate MAD maneuvers of pure pitch, rolls, and yaws. The pitch noise and roll signals are usually below 0.02 gamma. The worst-case yaw signal from a new production aircraft has been 0.04 gamma; however, during flight checks the aircraft easily met specifications. This ground check data may be useful if a search for disturbing magnetic influences becomes necessary.

Ordnance and Search Stores The aircraft can be compensated before the expenditure of ordnance and search stores, but be uncompensated after partial store disposal. The MK46 torpedo, which has a large magnetic moment, presents a serious problem. In this case, two methods for continuous compensation have been considered. One method is to calculate changes of the compensation settings for weapon configurations for various dropping sequences and use these settings after dropping. The other method is to fix a magnet of equal and opposite magnetic moment to the torpedo. This magnet drops free when the torpedo is released. Magnetic compensation of ordnance and search stores is the subject of a current Naval Air Development Center program.

**Lockheed Corporate Process Specification LCP70-1067A or B, Demagnetization Requirements of Ferromagnetic Aircraft Parts.*

DC Electrical Noise Ever since their inception, MAD sensors have been affected by dc power systems, because a dc current in a wire produces a magnetic field. Historically, dc power systems have not been regulated nor has their noise been suppressed to a level compatible with MAD sensors.

The P-3C is equipped with ac alternators, but there remain a few equipments that require dc sources of power. One of these is the VHF-VOR system whose equipments are located in the cockpit and in the J-2 rack, just forward of the F.S. 1117 pressure bulkhead. The power lines going to the J-2 rack pass near the DT-355/ASA-65 magnetometer. Since the ground return is the skin of the aircraft, a faulty electrical bond or loose cable on the equipment will cause an intermittent circuit or a source of noise.

In addition, the magnetic fields generated by power lines near the DT-355 magnetometer cause a problem in compensation. As long as the current remains steady, the field detected by the compensator magnetometer reacts as if there are additional components of permanent magnetic fields which are not attributable to the aircraft ferrous masses. On a day-to-day basis, this current remains relatively steady; however, there is an undesirable slow degradation of the state of compensation. Hence, it is important to use the MAD checklist to ensure that there is proper compensation for these magnetic fields.

Digital systems employ message trains between units for communications. If the grounds, shielding, bonds, etc., become faulty, these circuits can behave as though they are pulsing dc currents. On one occasion, a source of magnetic noise from the data lines was experienced between the Inertial Computer (H1 Rack) and the Inertial Position Indicator at the Nav-Comm Station. An unwanted short to chassis in the Position Indicator was the cause of this problem.

AC Electrical Noise A balanced three-phase power bus with twisted wires and a wire ground return will not disturb a MAD system since the magnetic fields created by the ac currents tend to cancel each other. However, in the case of the P-3C, some of the galley equipments are single phased, running from Main AC Bus B. Since the MAD system is powered from Main AC Bus A, oscillation problems can occur. This is known as "A-B buss interference". It was shown that a non-linear mixing of these two electrical sources takes place in the DT-355/ASA-65 Saturable Core Magnetometer. This occurs when the RPM's of No. 2 and No. 3 engines are very nearly the same, i.e., close enough to pass difference signals through the MAD sensor filters. An Engineering Change Proposal (ECP) to increase the drive on AN/ASA-65 magnetometers helped resolve this condition on some aircraft. This ECP also solved many other problems associated with the low AN/ASA-65 drive such as not having to match the magnetometer to its electronic control amplifier. In addition, it was decided to increase the MAD checklist in the NATOPS manual to include securing the galley B bus loads.

Avionic Equipment Noise The equipments listed in the MAD checklist in the P-3 Sensor Station 3 NATOPS manual have caused noise interference problems at one time or another. In addition, radio transmitters have also been the source of noise interference. During MAD operations these equipments should be employed with discretion since their use will cause disturbing influences at the MAD sensor head.

Electrical and avionic equipment that produce pulsing or cycling signals can also generate noise interference. Often the only way to isolate the source of these noises is by turning on and off equipments. This may take considerable patience, especially when the noise is intermittent. Checking the equipments on the NATOPS P-3 Sensor Station 3 MAD checkoff list is a good beginning. If the noise source cannot be isolated, then pull selected circuit breakers one at a time, at the various panels. Frequently the MAD operator may have to enlist the knowledge and aid of other crew members in order to intelligently troubleshoot MAD noise problems.

The lightning arrestor system may also cause bursts of noise, especially if the system is corroded or dirty. A lightning strike may be the first indication that the aft boom has not received enough attention. The resultant hole in the MAD boom indicates that compensation is required.

VARIOUS MAGNETIC FIELDS AFFECTING MAD OPERATION

Elementary MAD Detection Principles The theory of operation of magnetometers such as the AN/ASQ-10A and AN/ASQ-81 Sensors was presented in

Orion Digest Issue 26. Certain principles of magnetometer operation are necessary for a practical understanding of target detection and compensation. The previous article noted that the AN/ASQ-10A sensor was maintained parallel to the earth's field vector by a servo system. The presence of a large magnetic body such as a submarine causes a change in the earth's magnetic field intensity; that is, the lines of magnetic force are concentrated in the magnetic body and are no longer in a normal pattern. Since this change is quite small compared to the earth's field intensity, a means is provided to separate it from the relatively constant earth's field. (The AN/ASQ-81 is capable of measuring the total field; however, the P-3C MAD installation measures the difference between the two total field values.)

The MAD sensor detects the time variation of change of a magnetic field produced by a source which is superimposed on the earth's magnetic field vector. Although this task appears to be formidable, it is the very basis of MAD detection and MAD compensation.

The time variation of the magnetic field is provided by the movement of the aircraft relative to the target. The resultant frequency of the signal is very low (less than 1 Hz). Although the signal is spread over a band of frequencies, the center frequency of this signal can be determined by using the following "rule of thumb":

$$f = \frac{0.67\ V}{R}$$

where

f = Signal frequency in Hz

V = Aircraft velocity in knots (Target speed equals zero)

R = Slant range to target from aircraft in feet

Thus, for a velocity of 200 knots and a slant range of 1,000 feet, the signal frequency will be 0.134 Hz.

As a second example, if we fly an aircraft straight and level with or without the compensator, and without a target, the MAD recorder trace will remain as a reasonably straight line. This is apparent if we remember that even though the earth's magnetic field is distorted by the aircraft field, its field remains a constant with respect to time; hence, we detect no anomaly. (The AN/ASQ-10A detector sensor continuously lines up with the total field.) This simple principle permits us to determine whether a compensator is noisy; i.e., turn off the compensator while flying straight and level. If the noise is eliminated, the compensator is the culprit.

Another important point concerning the MAD sensor is the bandpass characteristics of its filter. The AN/ASQ-10A filter characteristics are displayed in Figure 4. The system is capable of employing a so-called notch filter (very narrow band rejection filter) at 0.0167 Hz. This filter is tuned to the frequency of the aircraft for a double rate turn. At a double rate turn, the aircraft completes a 360° turn in 60 seconds or 1/60 sec = 0.0167 Hz.

The AN/ASQ-81 bandpass filter characteristic is displayed in Figure 5 for corner frequencies 0.06 Hz and 0.6 Hz which are recommended for normal operation. Notice that the lower rejection slopes are so great that a notch filter is not required. The use of these filters will be demonstrated from time to time in this article. The importance of their phase characteristics also will be discussed.

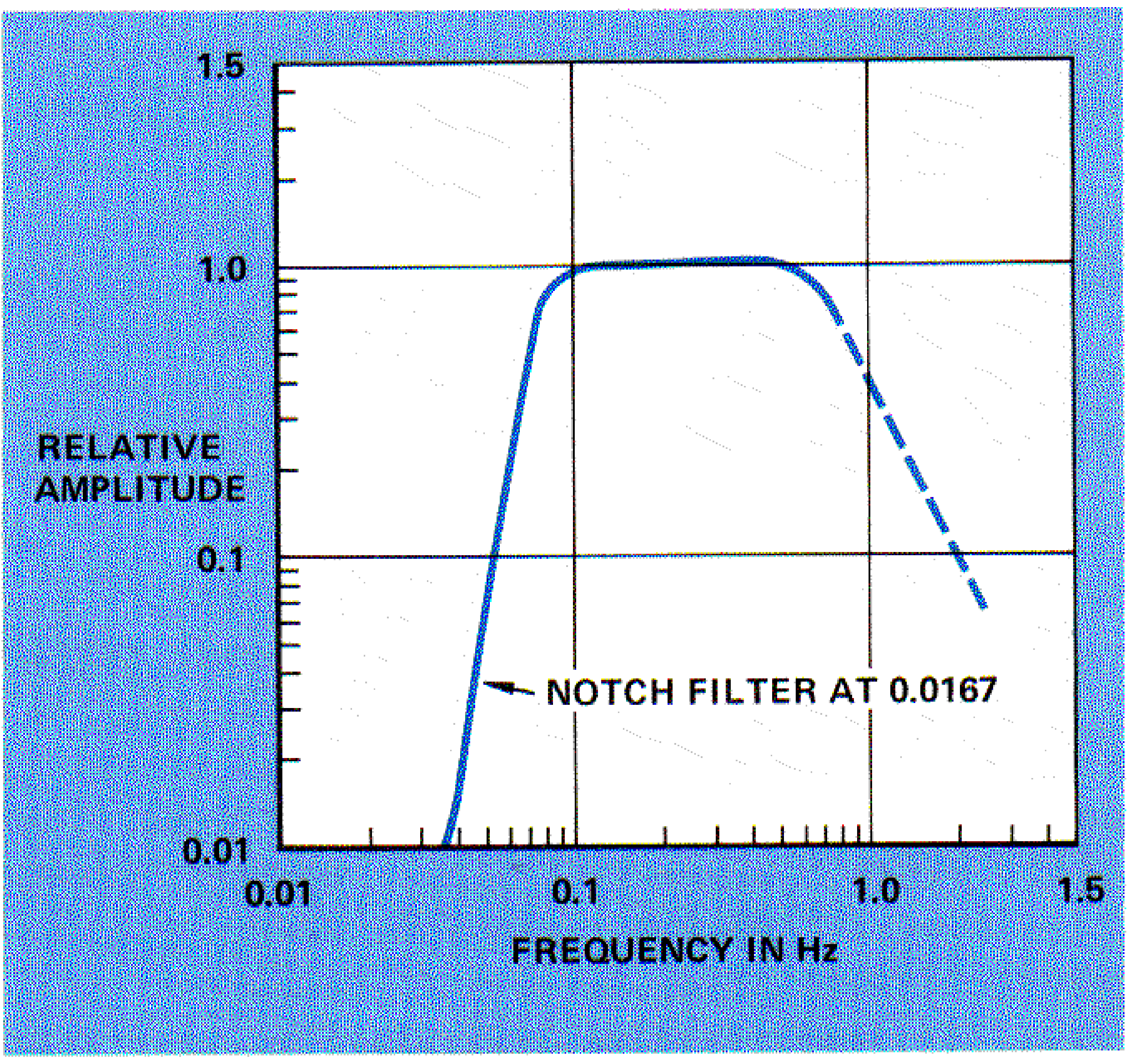


Figure 4. AN/ASQ-10A Filter Characteristics

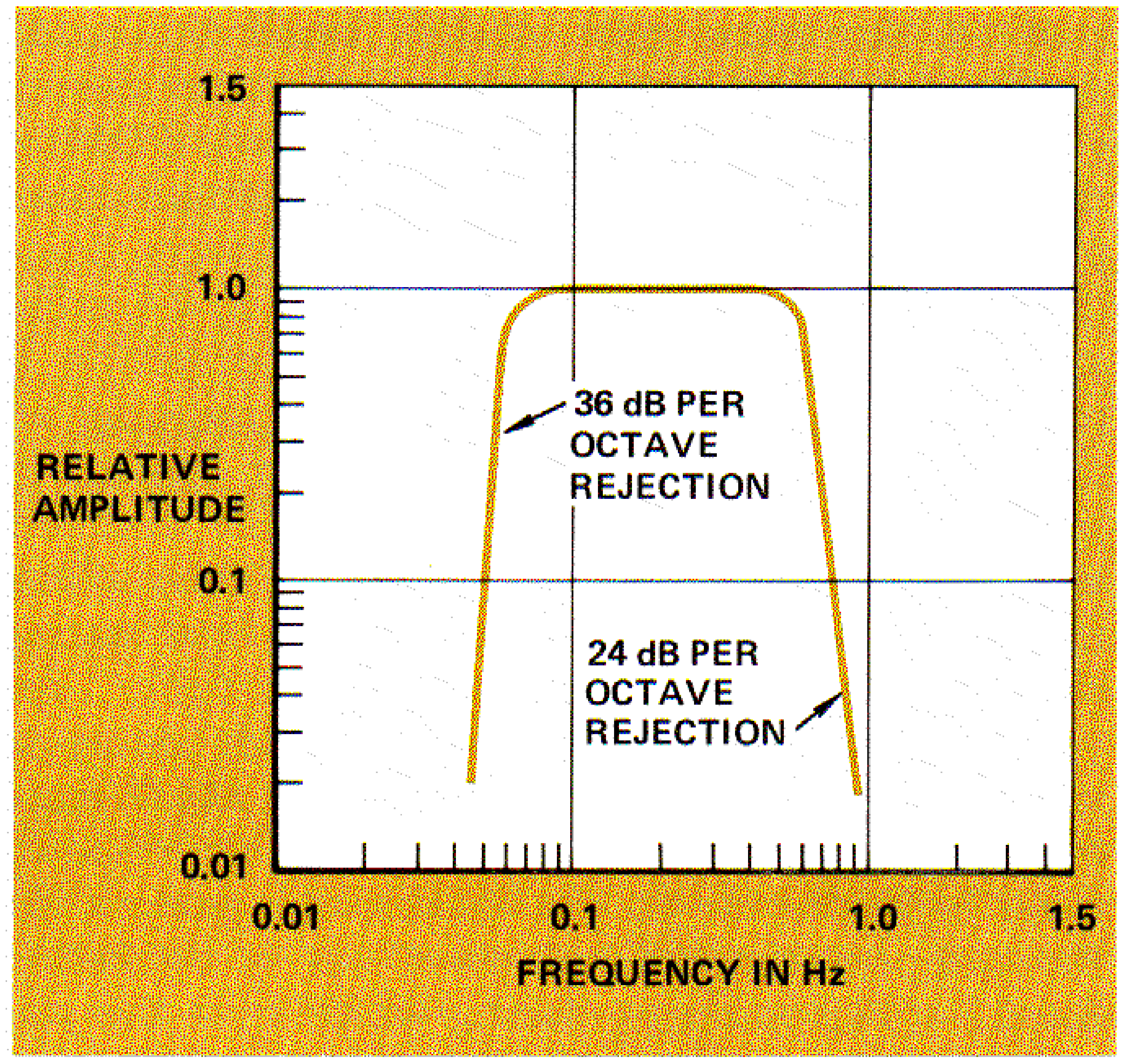


Figure 5. AN/ASQ-81 Filter Characteristics for 0.06 to 0.6 Hz

Mad Sensor Equipment Noise One of the noise sources affecting the operation of MAD is generated by the sensor equipment. Both the AN/ASQ-10A and AN/ASQ-81 can generate "self-noise"; however, each system has a characteristic pattern. Both systems employ sensitive amplifiers and other circuits which are subjected to the usual wide band noises associated with such circuits. A large part of this noise is reduced by the bandpass filters.

In the case of the AN/ASQ-10A, the detector sensor orientation is very important since a static misalignment of 2.3 minutes can cause a noise of 0.1 gamma and a dynamic stabilization error of 5 minutes can cause a noise of 0.05 gamma.* So, the sensors must be carefully aligned to eliminate this source of noise.

In the case of the AN/ASQ-81, the equipment noise should not exceed 0.016 gamma on any heading. At Lockheed, if a MAD sensor is suspected to be noisy, a test is performed in the Quality Assurance MAD Laboratory. These tests provide a Figure-of-Merit (FOM). An FOM is defined as the sum of peak-to-peak noise readings (in gamma) during standard maneuvers of roll, pitch, and yaw on the four cardinal headings. Ideally for a MAD sensitivity of 0.02 gamma, the FOM should be 3 x 4 x 0.02 = 0.24 gamma. (This test also is performed for acceptance testing of the equipment). If the equipment appears to be quiet on the ground, but noisy in the air, the sensor shockmounts should be inspected for breakage. Since the Magnetic Detector DT-323/ASQ-81(V) is a depot item, very little repair can be accomplished in the field.

An additional source of noise is caused by intermittent connections in the cables between the amplifier power supply and the sensor in the boom. The RG-58 coaxial cable connectors pass through two bulkhead fittings which are isolated from aircraft grounds. These fittings along with the terminal fittings at each end should be inspected for security. Also note that the star washers for bulkhead fittings should not be installed since they can cause a short to the aircraft structure causing ground loops.

The equipment noise of either the AN/ASQ-10A or AN/ASQ-81 is considered when determining the total aircraft system FOM. In fact, equipment noise is contained in the calculations 12 times, so it is important to reduce this noise or the aircraft FOM requirements will not be met.

Noise Due to Tactical Patterns (Horizontal Gradient) As was mentioned before, the earth's field has an average horizontal gradient of about 8 gammas per mile. In a standard MAD trapping circle of 2 minutes, the diameter of the circles for various speeds are as follows:

1.90 naut mi — 180 knots

2.12 naut mi — 200 knots

2.33 naut mi — 220 knots

It appears that noise excursions could exist between about 15 to 20 gammas on the recorder. However, the noise excursion frequency is 1/120 sec = 0.0083 Hz, and the filter of either MAD sensor rejects noise at this frequency. If some noise is displayed, its frequency is much lower than that of the target signal, hence the target can be distinguished from noise.

**Fromm, W.E. "The Magnetic Airborne Detector", Advances in Electronics, Vol IV, 257 (1952), Academic Press Inc., New York.*

Noise Due to Changes in Altitude (Vertical Gradient) It has been established that there is a maximum vertical gradient of approximately 0.01 gamma per foot. Thus, a noise signal can be developed by fast altitude changes or by pitching the aircraft.

The AN/ASQ-10A System has no means to compensate for noise signals caused by altitude changes. Thus, it is necessary for the pilot to avoid large altitude excursions while flying localization patterns; however, noise signals developed by fast let-downs to a localization pattern must be tolerated. It will be shown later that noise signals developed by a pitching aircraft can be minimized by compensation.

The AN/ASQ-81 has an altitude noise signal compensator which is located in the magnetic detector and connected to two static ports in the boom. This equipment provides a signal opposite to the noise signal generated by the aircraft in pitches. During a compensation flight the altitude compensator potentiometer (located on the AM-4535 Amplifier Power Supply) is adjusted in order to reduce the pitch signals on East-West headings. Due to the static port design, small unwanted signals are fed to the altitude compensator during yaw maneuvers. So, to measure the true FOM of the aircraft after compensation, the altitude compensator is turned off during yaw maneuvers. Since the compensation is performed at 10 to 14 thousand feet, additional compensation correction is required during MAD operations at trapping altitude (approximately 300 feet). After descent to trapping altitude, multiply the altitude compensator potentiometer setting by 0.75, then adjust the potentiometer to this value. This final setting should be approximately that listed in Table 1 for your geographic position. The altitude compensator will permit altitude changes in MAD maneuvers of ±300 feet. However, after a fast let-down from high altitude to the localization pattern the the compensator will not come out of saturation for 12 to 15 minutes, during which time the altitude compensator is unusable.

Natural Magnetic Noise Sources With the increased sensitivity of magnetic sensors such as the AN/ASQ-81, natural noises have become noticeable and restrict MAD use under certain circumstances.

Table 1. Altitude Compensator Setting for Different Geographical Locations (for Altitudes 1000 Feet and Below)

LONGITUDE

LATITUDE		EAST										WEST								LATITUDE
		0	20	40	60	80	100	120	140	160	180	160	140	120	100	80	60	40	20	
NORTH	80	3.12	3.14	3.19	3.25	3.32	3.37	3.38	3.37	3.34	3.33	3.32	3.31	3.31	3.29	3.26	3.21	3.16	3.31	80 NORTH
	70	2.98	3.02	3.11	3.25	3.39	3.49	3.50	3.43	3.32	3.26	3.27	3.34	3.41	3.43	3.37	3.23	3.13	3.03	70
	60	2.86	2.89	3.01	3.19	3.40	3.54	3.50	3.32	3.13	2.00	3.10	3.27	3.44	3.52	3.46	3.28	3.06	2.92	60
	50	2.70	2.76	2.89	3.08	3.29	3.44	3.36	3.09	2.82	2.72	2.82	3.07	3.32	3.47	3.43	3.22	2.94	2.77	50
	40	2.52	2.59	2.73	2.89	3.08	3.18	3.07	2.77	2.49	2.39	2.51	2.77	3.03	3.26	3.27	3.04	2.74	2.56	40
	30	2.38	2.36	2.50	2.64	2.79	2.84	2.72	2.45	2.19	2.13	2.24	2.45	2.67	2.82	2.98	2.78	2.46	2.29	30
	20	2.03	2.14	2.25	2.38	2.50	2.52	2.42	2.20	2.01	1.97	2.04	2.18	2.36	2.52	2.60	2.44	2.15	2.01	20
	10	1.86	1.97	2.07	2.19	2.32	2.35	2.27	2.12	1.97	1.92	1.93	1.97	2.06	2.10	2.20	2.10	1.87	1.79	10
	0	1.78	1.88	2.00	2.12	2.33	2.41	2.35	2.24	2.10	2.00	1.93	1.88	1.86	1.87	1.87	1.77	1.63	1.64	0
SOUTH	10	1.74	1.90	1.96	2.13	2.48	2.64	2.61	2.53	2.40	2.23	2.07	1.93	1.82	1.74	1.65	1.61	1.49	1.56	10 SOUTH
	20	1.69	1.84	1.89	2.24	2.73	3.02	3.06	3.00	2.76	2.56	2.32	2.11	1.76	1.77	1.58	1.41	1.39	1.52	20
	30	1.65	1.73	1.81	2.22	2.80	3.20	3.32	3.28	3.13	2.79	2.64	2.40	2.17	1.92	1.62	1.40	1.39	1.47	30
	40	1.64	1.69	1.85	2.32	2.93	3.41	3.60	3.59	3.44	3.20	2.96	2.73	2.48	2.15	1.78	1.51	1.47	1.54	40
	50	1.73	1.82	2.04	2.50	3.08	3.55	3.79	3.80	3.68	3.48	3.27	3.06	2.80	2.45	2.06	1.77	1.67	1.68	50
	60	2.00	2.11	2.34	2.73	3.20	3.62	3.86	3.91	3.83	3.69	3.53	3.35	3.10	2.78	2.44	2.17	2.03	1.98	60
	70	2.41	2.50	2.69	2.97	3.29	3.58	3.78	3.87	3.86	3.78	3.67	3.52	3.32	3.08	2.83	2.62	2.48	2.41	70
		0	20	40	60	80	100	120	140	160	180	160	140	120	100	80	60	40	20	
		EAST										WEST								

LONGITUDE

The three sources of natural noise are: geologic magnetic anomalies, geomagnetic field fluctuations, and ocean waves and swells.

Geologic Magnetic Anomalies The magnetic charts (Figures 1 and 2) indicate that the magnetic latitude lines are irregular. One reason for this phenomenon is that the earth is an inhomogeneous magnetic body. In this article the term "geologic anomaly" is applied to magnetic signals which have, as their source, magnetic anomalies occurring below the earth's surface and beneath the bottom of the ocean. For the purpose of MAD, these magnetic signals are considered to be noise and are caused by the motion of the MAD system through the spatial non-uniform magnetic field of the earth.

Generally, geologic noise is more pronounced in shallow water than in deep water because the detector is nearer to the source of the anomaly. In shallow water, geologic noise is actually the principal limitation of today's MAD systems. Magnetic anomalies caused by magnetic inhomogenities in the earth's crust are often associated with unusual bottom features such as sea mounts, ocean ridges, etc., and are stable noise sources over long periods of time. The absolute value of the anomaly will change very slowly with time, and its general shape will change even more slowly. If a certain operating area has substantial geologic noise at the present time, it will undoubtedly possess the noise for a long time.

During use of either the AN/ASQ-10A or AN/ASQ-81, if the noise level becomes extreme, it will be necessary to reduce system sensitivity until the noise background is at a tolerable level.

Geomagnetic Field Fluctuations Geomagnetic fluctuations are time variations of the earth's magnetic field which range in duration from fractions of a second to several days. The origin of these fluctuations is outside of the earth, mainly in the ionosphere. The fluctuations are caused primarily by the influence of the sun on the ionosphere in the form of solar electromagnetic radiation and charged particles (solar wind, etc.). Because of the solar influence on electric currents flowing in the ionosphere, the magnetic field at any point on the earth's surface varies diurnally, seasonally, and annually.

Diurnal variations are more or less smooth variations and occur regionally. The magnitude of these variations can be as large as several gammas, and the frequency ranges from a fraction of a Hertz to many Hertz.

Magnetic storms are sudden, pronounced, and erratic disturbances that are observable anywhere on earth. These storms arise because of solar activity and have a tendency to occur at the same time all over the earth. This type of variation is the most serious since the magnitude can reach hundreds of gammas. The periods are anywhere from fractions of a second to several minutes.

Rapid geomagnetic fluctuations of terrestrial origin (Van Allen belt, ionosphere, and thunderstorm activity) are called micropulsations. They generally range in amplitude up to a few gammas, although on rare occasions they may range up to several tens of gammas. The periods, again, are anywhere from nearly zero time to several minutes.

All these variations are relatively large in magnitude and occur in the frequency region in which submarine signals are received in the MAD equipment; therefore, they have a serious effect on the operational capability of MAD.

When Lockheed production flight test personnel encounter what they suspect to be magnetic storm activity, they confirm the activity through a radio call to the ground Quality Assurance Laboratory. This action assists in determining whether the source of noise is in the sensor, in some other equipment aboard the aircraft, or is a geomagnetic field fluctuation.

Figure 6 shows a graphic record of magnetic storm activity during 9 March 1973 taken at Lockheed's Quality Assurance Laboratory. This particular signal is a clean, sinusoidal wave with a period of approximately 20 seconds; however, such signals are not always as ideal as this one. Whenever noise is encountered, the operator must reduce the sensitivity of the MAD system until the noise is tolerable.

Magnetic Noise Produced by Ocean Waves and Swells The magnetic field generated by ocean waves is of importance when very sensitive magnetometers such as the ASQ-81 are operated at relatively low altitudes. The physical motion of a water wave in the presence of the earth's magnetic field is similar to the dynamo action in an electric generator; consequently, it will generate voltages and electric currents in the sea. These electric currents, in turn, generate magnetic fields which can extend significant distances above the surface of the sea and appear as magnetic noise at the MAD detector.

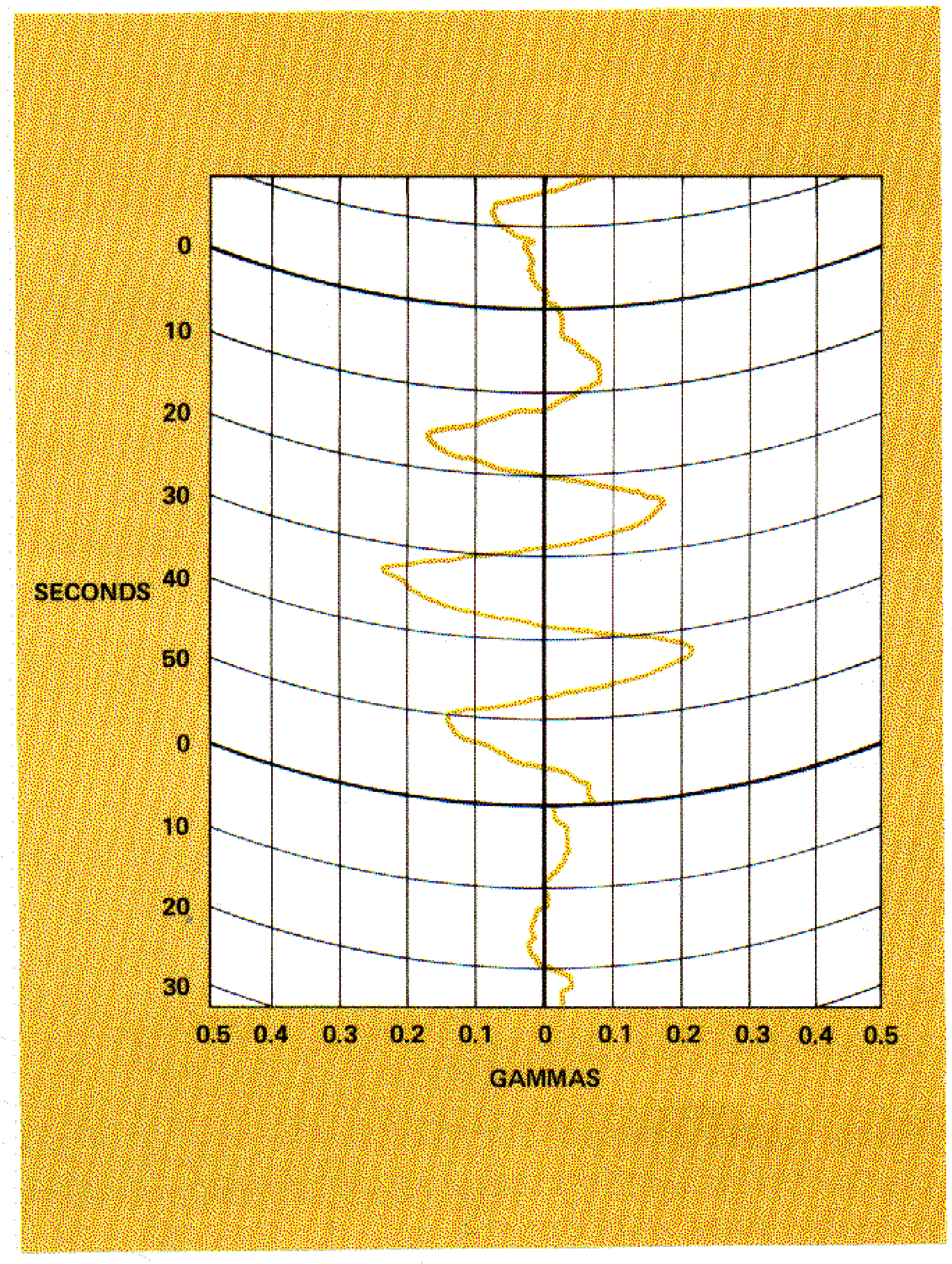


Figure 6. Geomagnetic Field Fluctuations

The magnitude of this induced magnetic field depends on various parameters. The highest amplitudes for any wave are produced when the wave moves at right angles to the earth's magnetic field lines (in an East-West magnetic direction). The amplitude also increases with increasing wave height and wave period. For instance, if two waves have the same period but one is twice the height of the other, the induced magnetic field amplitude of the higher wave will be twice that of the smaller wave. The amplitude of the field falls off exponentially with height; signals from long period waves fall off much less rapidly with altitude than do signals from short period waves.

The effective period is actually the real wave period modified by the aircraft motion over this wave. Flying directly along the swell produces a larger magnetic interference than flying 90° to the wave, which is due largely to the bandpass characteristic of the filter. When the aircraft is flying along the wave, the period of the wave (as it appears to the sensor in the aircraft) remains the same as the period of the wave with reference to earth coordinates. When the aircraft flys at an angle to the wave, the period appears much shorter to an observer on the aircraft as compared to a stationary observer on the sea surface.

The magnitude of the magnetic field to be expected from certain waves can be seen from the following example: Take two waves, both with a height of 2 feet, but one with a period of 7.5 seconds and the other with a period of 10 seconds. The following fields (in gamma) are produced:

	PERIOD	
ALTITUDE	7.5 Sec	10 Sec
100 ft	0.05 γ	0.18 γ
200 ft	0.01 γ	0.05 γ
300 ft	-	0.015 γ

Ocean waves with periods of around 7.5 seconds occur frequently in the North Atlantic, whereas 10-second period waves are not very frequent. However, waves with 20-second periods *can* occur and produce a magnetic field of more than 0.1 gamma at an altitude of 500 ft. Wave heights in the North Atlantic are between 2 and 3 ft about 40 percent of the time.

The preceding examples show that magnetic noise produced by ocean waves and swells is a problem at low altitudes, and that certain waves can cause interference at higher altitudes. Generally, it can be stated that magnetic disturbances from ocean wave noise should be absent most of the time at altitudes above 600 feet. Since effective MAD utilization depends in a large measure upon slant range to target, this latter altitude is very high for MAD tactics.

In summary, maximum interference from wave action occurs when you have an East-West sea and are flying along the swell (North-South). The higher the wave, the greater the interference.

Lockheed ORION Service Digest

COMPENSATION

ELEMENTARY THEORY A sinusoidal signal can be considered a noise signal because the signal has many of the statistical characteristics of a target and tends to hide small real target signals. Any signal that is not from a submarine target is unwanted; hence, it is called a noise signal.

In the previous section it was noted that certain natural magnetic noises occur over which we have little or no control. Now we shall discuss the first of a class of aircraft-generated magnetic noises over which we *do* have control. This class of noise is generated by components fixed to the aircraft in the vicinity of the sensor. The noise signals are generated at the aircraft maneuver frequency (or its harmonics, usually the second). Since this frequency is well within the bandpass of the MAD system, it must be cancelled by equal and opposite magnetic fields. This is called compensation.

There are passive, active, semi-automatic, and automatic compensation systems, and combinations thereof. The P-3A/P-3B aircraft employ a passive system for induced and eddy-current magnetic fields, while P-3C aircraft employ a semi-automatic active system. New systems are under development which use computers for automatic active and automatic passive systems.

AIRCRAFT MAGNETIC FIELDS There are three sources of magnetic fields associated with the airframe: permanent, induced, and eddy-current.

Permanent magnetic fields are usually associated with large ferromagnetic parts of the aircraft or with some of the aircraft's avionics equipments. This type of field is fixed in the aircraft frame of reference, thereby changing its orientation to the earth's field vector during aircraft maneuvers and causing a field change in the vicinity of the AN/ASQ-10A or AN/ASQ-81 magnetometer. In the case of the P-3C, the aft AN/APS-115 Radar Magnetron is the primary contributor to the aircraft's permanent magnetic field component.

Induced fields are created in aircraft ferromagnetic structures and components by the earth's magnetic field. These fields are usually associated with soft iron parts of the aircraft, although they also occur to a limited extent in hard steel parts. Field polarity and magnitude are determined by the direction and magnitude of the earth's magnetic field and by aircraft orientation to the earth's field. Hence, the magnitude and orientation of induced magnetic fields vary with respect to the aircraft coordinate system as the aircraft maneuvers.

All of the aircraft skin, ribs, frames, etc. are eddy-current sources. These currents are caused by the relative time rate of change of the earth's magnetic field to the aircraft as the aircraft maneuvers. (The same principle upon which electric generators operate.) When eddy currents are created in large sheets of metal (wings, fuselage, etc.), they cause a magnetic field in the direction perpendicular to the plane of the conducting sheet.

A mathematical analysis set up an aircraft frame of reference with respect to the earth's field vector.* The following magnetic fields are thereby defined:

**P. Leliak, "Identification and Evaluation of Magnetic Field Sources of Magnetic Detector Equipped Aircraft IRE Transactions on Aerospace and Navigational Electronics", February 1971 (Unclassified)*

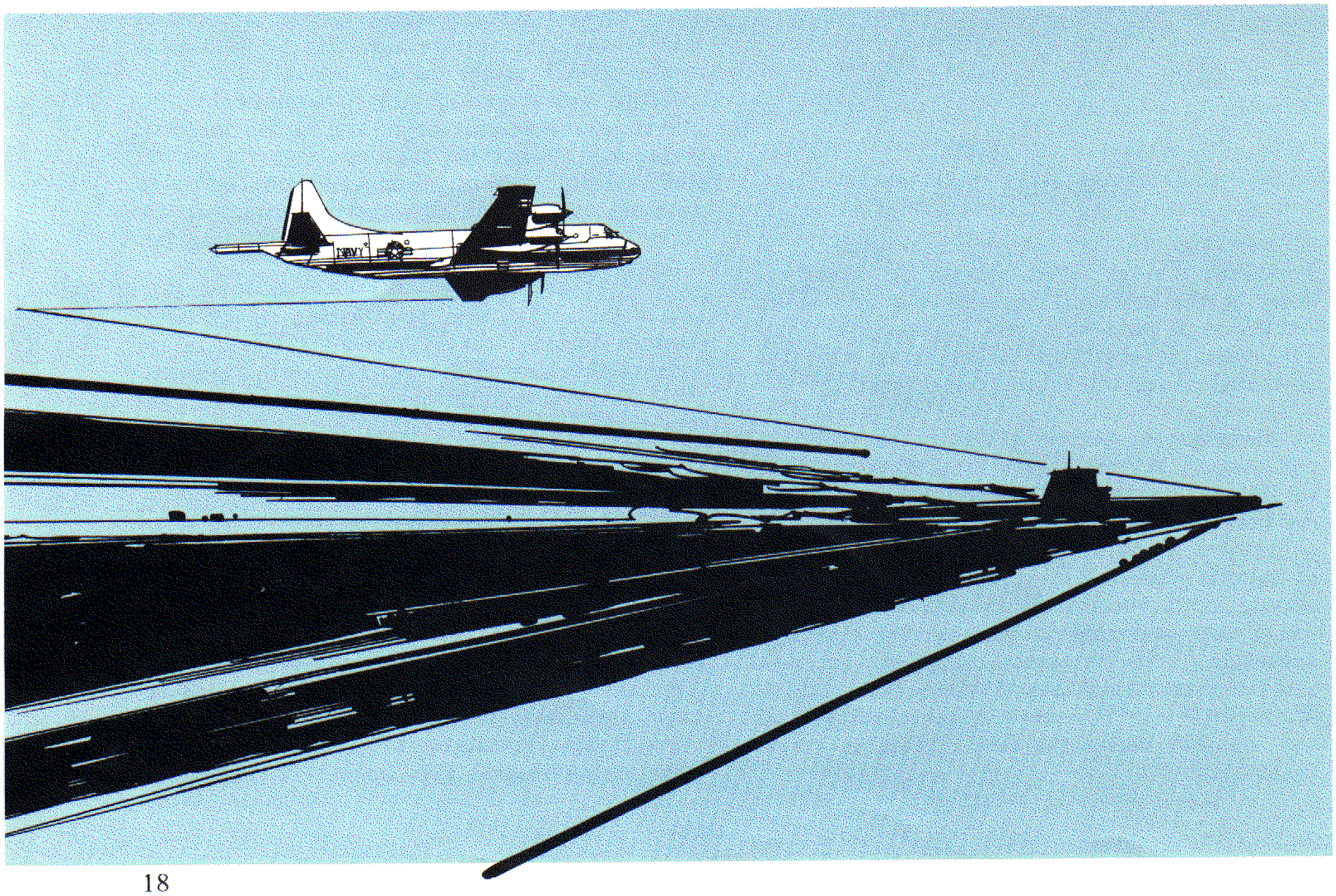
Permanent Terms All sources of permanent magnetic fields in the aircraft combine to give the effect of a single permanent magnetic field at the detector location. This may be resolved into three component fields or terms*, each parallel to one of the aircraft's principal axes: transverse T, longitudinal L, and vertical V. The amplitude of these T, L, and V terms is constant, and the noise they generate is nearly in phase with the aircraft maneuver.

Induced Terms The earth's magnetic field is the source of induced magnetism in the aircraft. The aircraft's induced magnetic field, like its permanent field, can be resolved into transverse, longitudinal, and vertical components or sources, each parallel to one of the aircraft's inflight axes.

Each source produces a magnetic field which crosses the sensor (at the end of the boom). Each of these induced fields can be further resolved into three sub-components that are parallel to the T, L, and V axes of the aircraft at the sensor. Hence, there are a total of nine components (terms) which are derived and are denoted as: TT, TL, TV, LT, LL, LV, VT, VL, and VV. The first letter of the component denotes either the transverse (T), longitudinal (L), or vertical (V) source of the aircraft's induced magnetic field; the second letter denotes the T, L, or V magnetic components caused by their respective sources at the MAD sensor. For example, the TV component denotes the transverse source of the aircraft's induced magnetic field as it is detected at the MAD sensor.

The longitudinal source can be visualized as a long, wide bar magnet running along the longitudinal axis of the aircraft. The L component of the aircraft's induced magnetic field emanates from the stern of the aircraft and can cross the magnetic detecting head in any direction. As in the previous example, the L source can be further resolved into T, L, and V sub-components. For P-3C aircraft, the LL term is large while the LV term is very small and LT is nearly zero.

"Term" refers to one component of a given magnetic field.



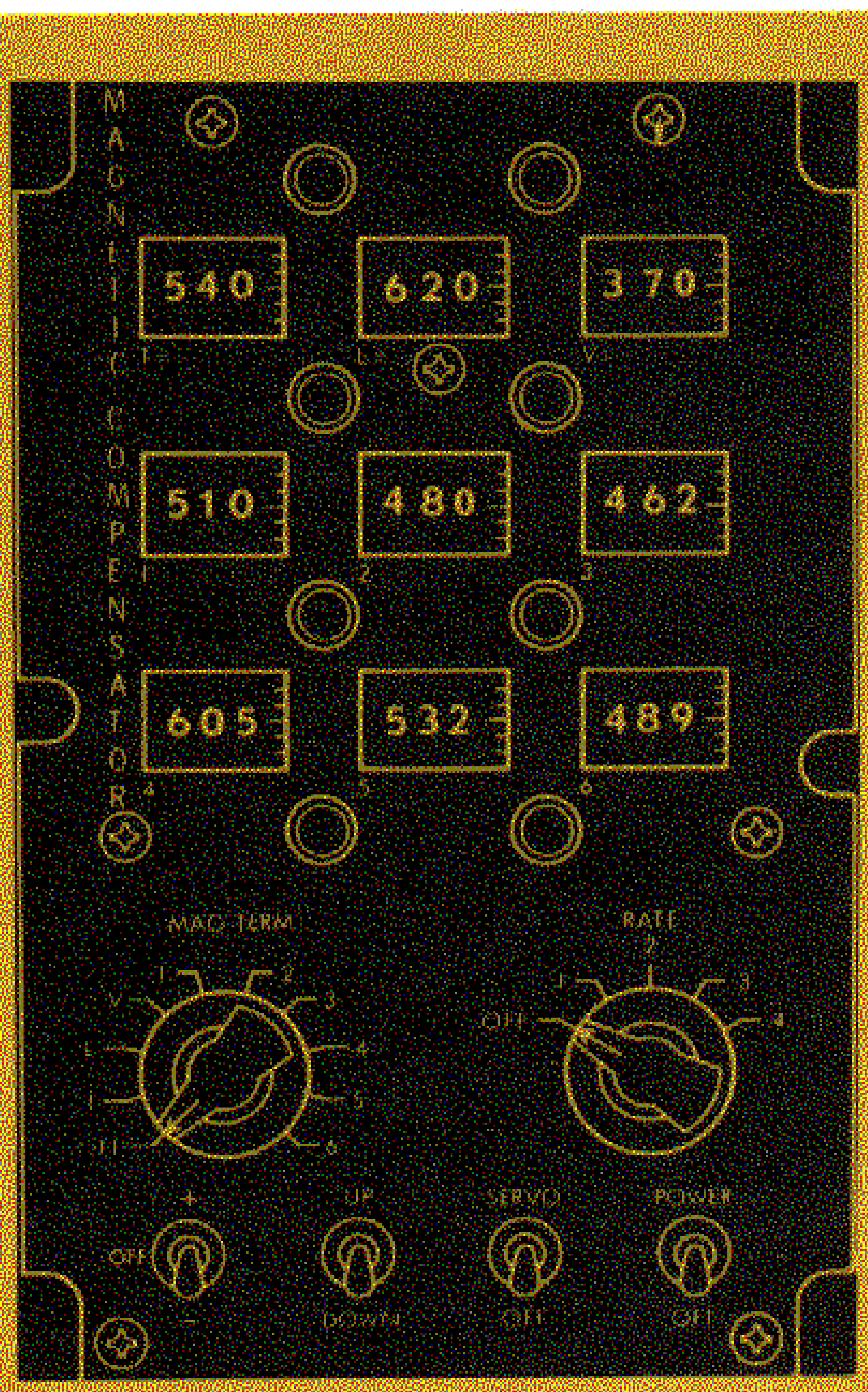
The polarity of the aircraft's induced fields can change with the orientation of the aircraft to the earth's magnetic field. Since the L source is induced by the earth's horizontal magnetic field which is directed north, the L source strength is maximum in one direction when the aircraft heading is magnetic North and maximum in the other direction when the heading is magnetic South.

Analysis has proved that these components can be combined to form five pairs which behave identically, no matter how the aircraft maneuvers: VV-TT, VV-LL, TL+LT, TV+VT, and LV+VL. The intensity of the aircraft's induced fields depends on the strength of the earth's field and the orientation of the aircraft to it. An induced field is nearly in phase with aircraft maneuver.

Eddy-Current Terms All eddy-current sources produce magnetic fields which, when resolved, also result in nine components at the detector. These components are denoted in the same manner as the induced terms, but with lower case letters. In two cases, terms act in opposition and can be combined. Thus, (tt −ll) and (vv −ll) can be formed; these are referred to as pure terms. There exists a total of eight eddy-current components which are composed of the two pure terms and six cross terms (tl, tv, lt, lv, vt, and vl). As in the case of the induced fields, the intensity of eddy-current fields depends on the strength of the earth's field and the aircraft's alignment with it. In addition, the eddy-current fields are proportional to the rate of change of aircraft attitude. Thus, the noise signal is approximately 90 degrees out of phase with the maneuver signal, and its amplitude is proportional to the maneuver rate. As an example, eddy-current fields are zero when the aircraft is flying straight and level.

AN/ASA-65 MAGNETIC COMPENSATION GROUP The 9-Term Compensator (9 TC) consists of four elements which perform the following functions:

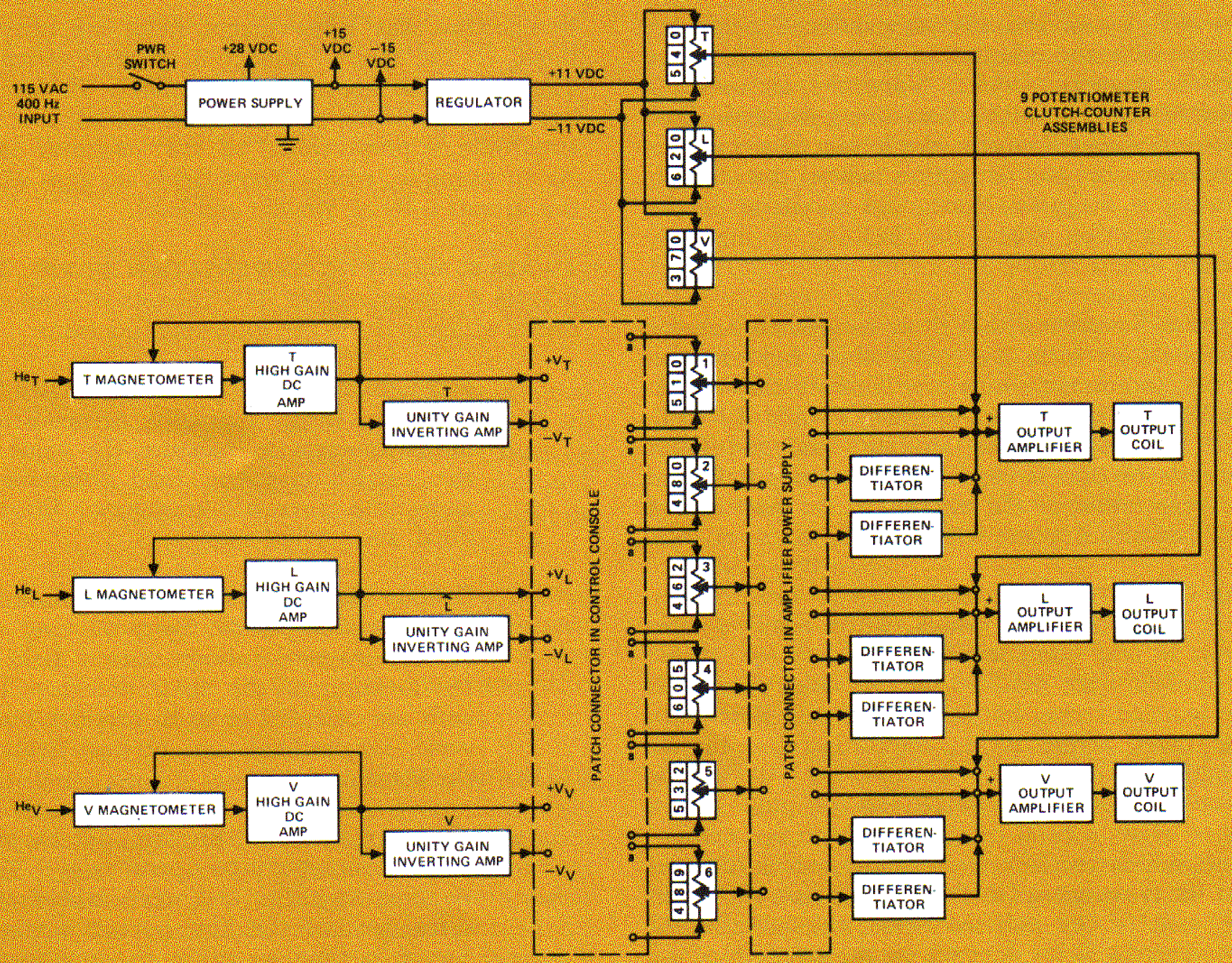
1. Magnetometer Assembly – This assembly contains three mutually perpendicular magnetometers to measure the value of the earth's magnetic field components along the aircraft's transverse, longitudinal, and vertical axes.
2. Output Coil Assembly – This assembly contains three coils for producing the correct magnetic compensation field at the location of the MAD detector. The coils are oriented so as to produce transverse, longitudinal, and vertical fields at the MAD detector.
3. Control Console – This unit contains the controls necessary to operate the 9 TC. A servo amplifier and servo motor can drive each of the nine potentiometers, one at a time, to adjust the amplitude of the compensating fields.



4. Amplifier Power Supply – This unit contains the power supplies and all the electronics required to amplify the magnetometer signals, drive the output coils and correlate the MAD signal with aircraft maneuvers.

The principles of operation of the 9 TC are as follows: Each of three output coils is driven by a summing amplifier. The three permanent fields are compensated by a constant direct current source. Each field's magnitude is adjusted by a potentiometer marked T, L, or V. (See Figure 7 for the 9 TC Block Diagram.)

Figure 7. 9-Term Compensator Control Panel and Compensator Block Diagram – Compensation Circuit



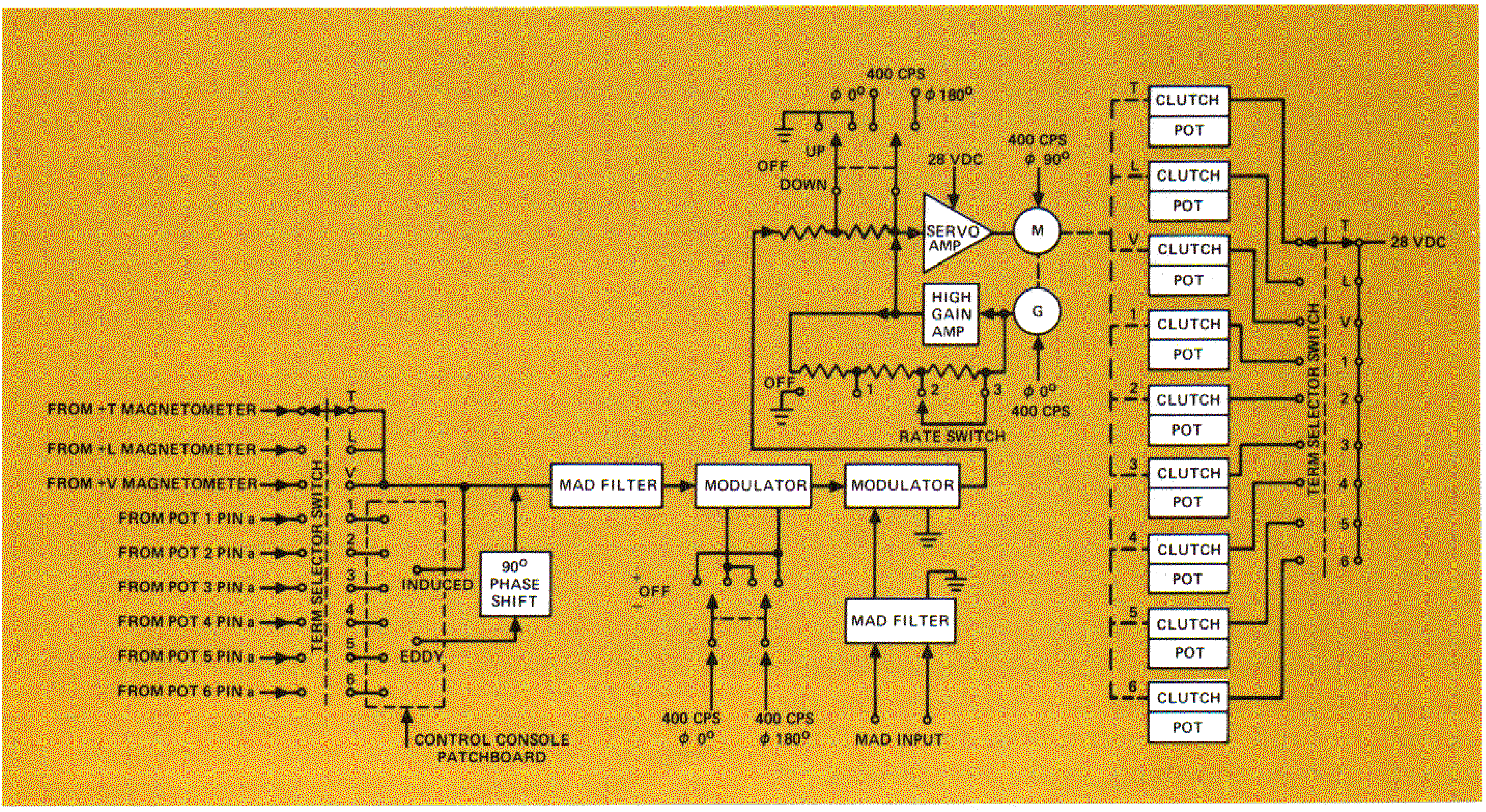


Figure 8. 9-Term Compensator Block Diagram – Term Adjustment Circuit

The six remaining term adjustments in the 9 TC are employed to approximately compensate the 13 remaining aircraft components. To compensate for induced terms, the magnetometer measures the components of the ambient field. These values are applied to a potentiometer which produces an output proportional to the magnetic field measured. This signal is then sent to the summing amplifier to drive the appropriate output coil. For example, the T magnetometer is connected to the L coil to compensate for TL induced magnetic term. Since LT and TL behave together as the LT + TL induced term, this one compensator arrangement will compensate for both aircraft terms. In the case of the components (VV–TT) and (VV-LL), we must select two terms which, for the P-3C, are VV and -LL.

For eddy-current terms, the compensation method is the same as for induced terms except that the maneuver signal is passed through an analog differentiator circuit before sending it to the summing amplifier. Thus, the maneuver signal is phase-shifted 90° in order to match the eddy-current signals. The eddy-current compensator terms are proportional to the time-rate-of-change of the earth's magnetic field with reference to the aircraft's coordinate system.

Operation of the 9-Term Compensator is further described by the block diagram shown in Figure 8. This circuit is provided as an aid in trimming to zero each term under consideration. The rectangles labeled "modulator" comprise a correlator for comparing the output of the MAD set versus a selected term from the 9 TC. The output from the correlator drives a servo motor, which in turn drives the selected term potentiometer in the compensator. The output signal from the selected term potentiometer is filtered by a bandpass filter, the same as that employed by the MAD detector, so that both signals will have the same phase and time delays.

The 90-degree phase shifter is also employed in the case of eddy-current compensation. The maneuver signal is modulated by a 400-Hz signal and then multiplied by the MAD signal. The correlator circuit produces a signal if MAD and the compensator signals are in phase. This continues until the output of the AN/ASQ-81 Detector is zero. This will occur when the 9-TC output coil generates a signal equal in amplitude but opposite in polarity to the signal generated by the airplane maneuver. When permanent fields or induced fields are compensated in the presence of eddy-current fields, the system will oscillate around the correct potentiometer setting. The rate switch is provided to reduce these oscillations to a minimum.

Since this one operation of the Term Adjustment Circuits is automatic, it has given the mistaken impression that the 9 TC is an automatically compensated system.

There are two subtle problems that can arise with the AN/ASQ-65 compensator servo system. On rare occasions, the MAD signal from the AN/ASQ-81 MAD sensor can be reversed. When this happens the compensator servo will run to one extreme or the other. For the moment, operation of the servo can be corrected by reversing the position +OFF- Polarity Selector Switch on the control indicator panel. If proper servo operation is obtained with the switch reversed during all maneuvers, the MAD signal is reversed. Trouble can reside in the 2A10 three-card module.

The other compensator servo problem is caused by a faulty MAD Maneuver Programmer in the aircraft autopilot. There is a tendency for the autopilot to roll the aircraft a little slowly. If the aircraft maneuvers aren't brisk, the phasing of the MAD signal is beyond the bandpass of the AN/ASA-65 servo filter board. Therefore, if the T or V servo runs sluggish, request the pilot to manually increase the aircraft maneuver rates.

The standard aircraft maneuvers are:

1. Roll - The aircraft shall be rolled ± 10 degrees, with a period of 4 to 8 seconds. Heading and pitch shall be maintained to within ± 1 degree.
2. Pitch - The aircraft shall be pitched ± 3 degrees with a period of 3 to 6 seconds. Altitude variations shall be held to a minimum, and in no case shall exceed 50 feet. Roll and yaw shall be maintained to within ± 1 degree.
3. Yaw - The aircraft shall be yawed through heading changes of ± 5 degrees, with a period of 4 to 8 seconds. A zero roll angle shall be maintained to within ± 1 degree.

For P-3C aircraft equipped with the AN/ASQ-10, compensation of the LV term is required since one of the servos in the AN/ASQ-10 is asymmetrical. Since the ASQ-81 Detector has no moving parts (hence, no servo) it has been determined that the LV has less effect on the detector than the vl term, so the vl term is compensated instead of the LV term.

Bronstein and Randle* have developed expressions for MAD maneuver signals which can be employed to derive expressions from which the aircraft independent interference fields can be solved for in several ways. One way is to measure the in-phase and quadrature interference signals directly. The second is to null the in-phase and quadrature interference signals by producing equal and opposite signals.

In actual practice, only one or two equations must be solved for the P-3C with the AN/ASQ-10; namely, the LV term. In the case of the AN/ASQ-81 no calculations of this nature are necessary.

Experimental Determination of Terms As noted, theoretically the aircraft magnetic sources can be composed into 16 independent magnetic terms. Fortunately, all terms are not manifested on all headings or maneuvers. In addition, some terms are small enough to be ignored. In order to experimentally measure these components, the autopilot MAD Maneuver Programmer is employed to perform certain unorthodox maneuvers to separate these terms. These maneuvers are performed on magnetic cardinal headings and consist of pure rolls without heading change or pitching, pure yaws without rolling or pitching, and pure pitches without rolling or yawing.

In the previously mentioned paper, Leliak derived a set of linear equations for these various maneuvers for the magnetic cardinal headings. The results of this paper are contained, in a modified form, in Tables 2 and 3. These values are for an earth's field of 50,000 gammas and standard maneuver amplitudes and rates. The values are dip angle dependent with the dip angle denoted as ϕ. The lower half of each table is comprised of eddy-current terms which are 90° out of time phase with the upper-half terms.

To interpret Tables 2 and 3 it is important to know that the fundamental signal on a North roll, which is in time phase with the maneuver signal, is as follows:

$$S_{NR} = 0.349 \sin \phi (T) + 0.175 \sin 2 \phi (TL + LT)$$
$$+ 0.349 \sin^2 \phi \ (TV + -VT)$$

L. Bronstein and P. Randle, "Magnetic Compensation Procedures for MAD-Equipped ASW Aircraft", Technical Memorandum TM-1255, 19 August 1965, Electronic Division of CAE Industries Ltd.

Table 2. Values of the Fundamental Signal Coefficients for Standard Maneuvers on Cardinal Headings

Component	North-South			East-West		
	Roll	Pitch	Yaw	Roll	Pitch	Yaw
T	$0.349 \sin\phi$		$\mp 0.175 \cos\phi$	$0.349 \sin\phi$		
L		$0.175 \sin\phi$			$0.175 \sin\phi$	$\pm 0.175 \cos\phi$
V		$\mp 0.175 \cos\phi$		$\mp 0.349 \cos\phi$		
TT				$\mp 0.349 \sin 2\phi$		
LL		$\mp 0.175 \sin 2\phi$				
VV		$\mp 0.175 \sin 2\phi$		$\mp 0.349 \sin 2\phi$		
TL + LT	$\pm 0.175 \sin 2\phi$		$-0.175 \cos^2\phi$		$\pm 0.087 \sin 2\phi$	$0.175 \cos^2\phi$
TV + VT	$0.349 \sin 2\phi$		$\mp 0.087 \sin 2\phi$	$-0.349 \cos 2\phi$		
LV + VL		$-0.175 \cos 2\phi$			$0.175 \sin^2\phi$	$\pm 0.087 \sin 2\phi$
tt				$\pm 0.172 \sin 2\phi$		
ll		$\mp 0.087 \sin 2\phi$				
vv		$\mp 0.087 \sin 2\phi$		$\mp 0.172 \sin$		
tl	$+0.174 \sin 2\phi$		$-0.175 \cos^2\phi$			
tv	$0.346 \sin^2\phi$		$\mp 0.087 \sin 2\phi$	0.0027 $+0.3437\ \mathrm{Sin}^2\phi$		
lt					$\pm 0.087 \sin 2\phi$	$0.175 \cos^2\phi$
lv		$0.175 \sin^2\phi$			$0.175 \sin^2\phi$	$\pm 0.087 \sin 2\phi$
vt	$-0.0027 \sin^2\phi$			-0.0027 $-0.3437\ \mathrm{Cos}^2\phi$		
vl		$-0.175 \cos^2\phi$				

Table 3. Values of the Second-Harmonic Signal Coefficients for Standard Maneuvers on Cardinal Headings

Component	North-South			East-West		
	Roll	Pitch	Yaw	Roll	Pitch	Yaw
T				$\pm 0.015 \cos\phi$		$\pm 0.004 \cos\phi$
L		$\pm 0.004 \cos\phi$	$\pm 0.004 \cos\phi$			
V	$0.015 \sin\phi$	$0.004 \sin\phi$		$0.015 \sin\phi$	$0.004 \sin\phi$	
TT	$-0.030 \sin^2\phi$		$-0.008 \cos^2\phi$	$0.030 \cos 2\phi$		$0.008 \cos^2\phi$
LL		$0.008 \cos 2\phi$	$0.008 \cos^2\phi$		$-0.008 \sin^2\phi$	$-0.008 \cos^2\phi$
VV	$0.030 \sin^2\phi$	$-0.008 \cos 2\phi$		$-0.030 \cos 2\phi$	$0.008 \sin^2\phi$	
TL + LT						
TV + VT				$\pm 0.030 \sin 2\phi$	$\pm 0.002 \sin\phi$	$\pm 0.002 \sin 2\phi$
LV + VL	$\pm 0.008 \sin 2\phi$	$\pm 0.008 \sin 2\phi$	$\pm 0.002 \sin 2\phi$			
tt	$0.030 \sin^2\phi$		$0.008 \cos^2\phi$	$-0.030 \cos 2\phi$		$-0.008 \cos^2\phi$
ll		$-0.008 \cos 2\phi$	$-0.008 \cos^2\phi$		$0.008 \sin^2\phi$	$0.008 \cos^2\phi$
vv	$-0.030 \sin^2\phi$	$0.008 \cos 2\phi$		$0.030 \cos 2\phi$	$-0.008 \sin^2\phi$	
tl						
tv				$\mp 0.030 \sin 2\phi$		$\mp 0.004 \sin 2\phi$
lt						
lv		$\mp 0.008 \sin 2\phi$	$\mp 0.004 \sin 2\phi$			
vt				$\mp 0.030 \sin 2\phi$	$\mp 0.004 \sin 2\phi$	
vl	$\mp 0.015 \sin 2\phi$	$\mp 0.008 \sin 2\phi$				

NOTE: **Where coefficients are preceded by two polarity signs, the upper sign refers to North or East headings and the lower sign refers to South or West headings.**

Table 4. AN/ASA-65 Configuration BEFORE Nomenclature Change

Aircraft Installation	ASA-65/ASQ-10A P-3C	ASA-65/ASQ-81 P-3C
Magnetic Compensator Group	AN/ASQ-65	AN/ASA-65A
Control Indicator (Unit 1)	C-7718/ASA-65	C-7718A/ASA-65 (Orange Dot) or C-7718/ASA-65 (Orange Dot)
Patch Connector 1P2	51716	51716 (Orange Dot)
Servo Board 1A2	51144 or 55551 (ECP 002)	55551 (Only)
Amplifier Electronic Control (Unit 2)	AM-6056/ASA-65	AM-6056A/ASA-65 (Orange Dot) or AN-6056/ASA-65 (Orange Dot)
Patch Connector 2P3	51730	51730 (Orange Dot)
Output Board 2A2, 2A3, 2A4	51069*	51069*
Filter Board	51071	62004
Magnetometer Board 2A6, 2A7, 2A8	51070 or 55455	55455 (Only)
Magnetometer (Unit 3)	DT-355/ASA-65	DT-355/ASA-65
Coil Magnetic Compensating (Unit 4)	MX-8130/ASA-65 (1 unit)	MX-8130A/ASA-65 (3 units)

*** Before permanently replacing an Output Amplifier Board 2A2, 2A3 or 2A4 even though part numbers may be identical, check output board scale factor setting and adjust as required in accordance with current maintenance instructions.**

The fundamental signal on a North roll which is 90° out of phase with the maneuver signal is as follows:

$$S_{NR} = +0.174 \sin 2 \phi \,(tl) + 0.346 \sin^2 \phi \,(tv) - 0.0027 \sin^2 \phi \,(vt)$$

In most cases of compensation these tables are used in a qualitive manner; i.e., determination of existence of a term, its sign and a rough idea how its size compares with other terms during the special maneuvers. In the equations above, the terms as denoted by capital and lower case letters are employed as coefficients. These are constants for a particular aircraft, and we are determining their magnitude by compensation.

P-3C COMPENSATOR INSTALLATIONS The AN/ASA-65(V) Magnetic Compensator Group was conceived, developed, designed, and manufactured by CAE Electronics Ltd of Montreal, Quebec, Canada. The equipment has recently received new nomenclature; thus those designations will be employed in this article. In addition to the new nomenclature, the equipment has received new changes, all of which are now being delivered in the production of P-3C's. A CAE Electronics Ltd field team is preparing to retrofit these changes in the field. Tables 4 and 5 include the new nomenclature and changes for the AN/ASA-65(V) Magnetic Compensator Group.

The equipment employed in the P-3C includes two installation configurations which consist of the following:

1. Compensator Group, Magnetic AN/ASA-65(V)1

UNIT	TYPE DESIGNATION
Control Indicator	C-7718/ASA-65(V)
Amplifier, Electronic Control	AM-6056/ASA-65(V)

Table 5. AN/ASA-65 Configuration AFTER Nomenclature Change

Aircraft Installation	ASA-65/ASQ-10A P-3C	ASA-65/ASQ-81 P-3C
Magnetic Compensator Group	AN/ASA-65(V)1	AN/ASA-65(V)2
Control Indicator (Unit 1)	C-7718/ASA-65(V)	C-8935/ASA-65(V)
Patch Connector 1P2	51716	65562
Servo Board 1A2	55551	55551
Amplifier Electronic Control (Unit 2)	AM-6056/ASA-65(V)	AM-6459/ASA-65(V)
Patch Connector 2P3	51730	65563
Output Board 2A2, 2A4	51069*	51069* or 68066-01* (ECP006)
Output Board 2A3	△1 52863*	△1 52863* or 68066-02* (ECP006)
Filter Board 2A5	51071	62004
Magnetometer Board 2A6, 2A7, 2A8	52875 or 52888	52875 Only
Magnetometer (Unit 3)	DT-355/ASA-65(V)	DT-355/ASA-65(V)
Coil Magnetic Compensating (Unit 4)	MX-8130/ASA-65(V) (1 Unit)	MX-8897/ASA-65(V) (3 Units)

* Before permanently replacing an Output Amplifier Board 2A2, 2A3 or 2A4, even though part numbers may be identical, check output board scale factor setting and adjust as required per maintenance instructions for a particular installation.

△1 Keying of 52863 and 68066-02 boards is identical to keying of 51069 and 68066-01 boards. Care must be exerted to preclude interchanging.

Magnetometer Assembly	DT-355/ASA-65(V)
Coil Assembly, Magnetic Compensating	MX-8130/ASA-65(V)

2. Compensator Group, Magnetic AN/ASA-65(V)2

UNIT	TYPE DESIGNATION
Control Indicator	C-8935/ASA-65(V)
Amplifier, Electronic Control	AM-6459/ASA-65(V)
Magnetometer Assembly	DT-355/ASA-65(V)
Coil, Magnetic Compensating	MX-8897/ASA-65(V)

The AN/ASA-65(V)1 and (V)2 are employed for the AN/ASQ-10A and AN/ASQ-81 equipped P-3C aircraft respectively. Equipment locations are shown in Figure 9.

The two Control Indicators differ in that their patch connectors are wired for different terms.

The two Electronic Control Amplifiers differ in two ways: the patch connectors are wired for different terms, and the filter board characteristics are matched to their respective MAD sensors (ASQ-10A and -81).

The Magnetometer Assemblies DT-355/ASA-65(V) are the same for each installation; however, the actual location of the installations differ. The magnetometer assembly for the AN/ASQ-10A is located at the intersection of the aft radome and the MAD stinger (cylinder), while the magnetometer assembly for the AN/ASQ-81 installation is located at Fuselage Station 941 (overhead near the lavatory). The reason for this difference is that

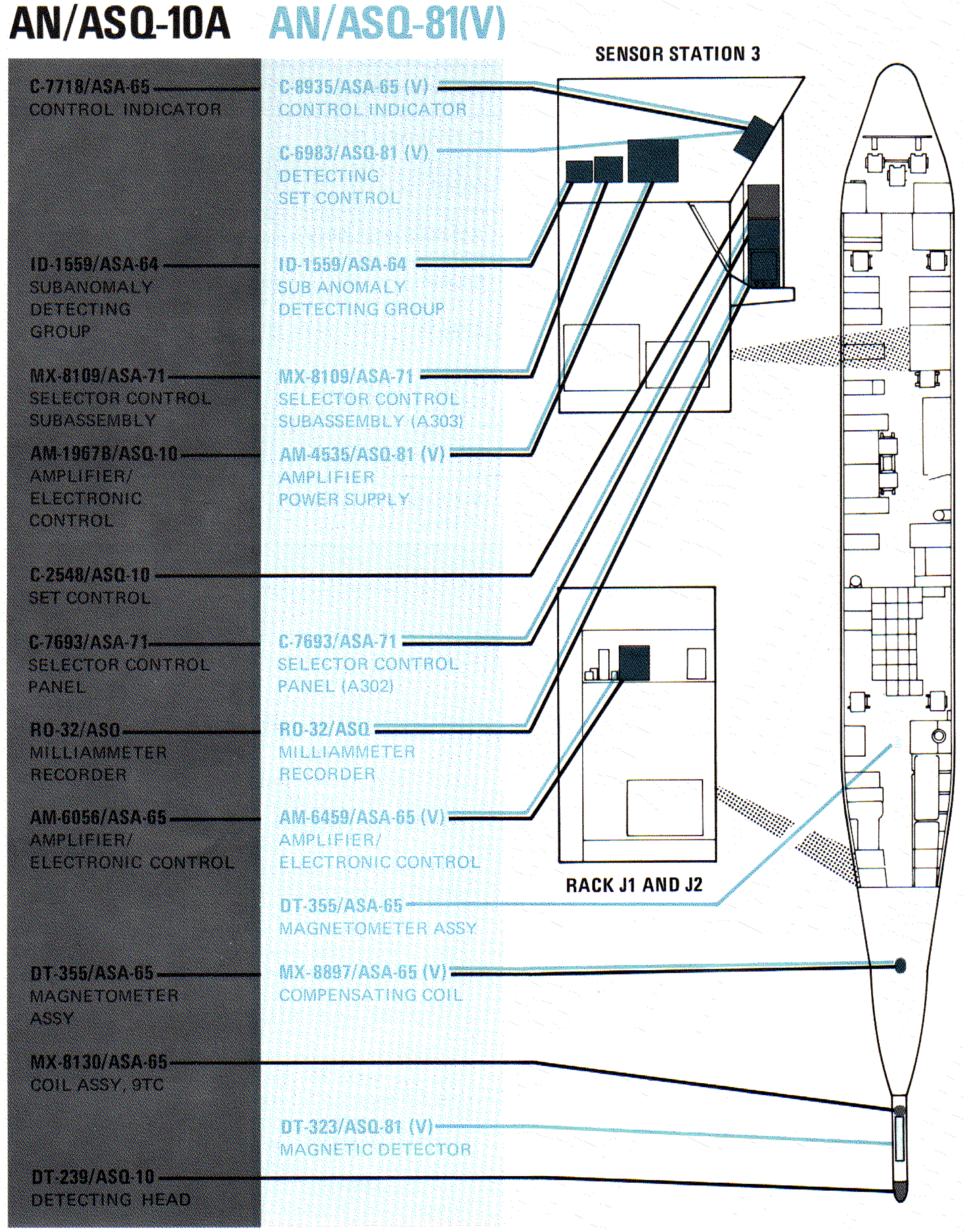


Figure 9. AN/ASQ-10A and AN/ASQ-81(V) Installations

the AN/ASQ-65(V)2 has large output coils which originally caused oscillations because of feedback between the ASA-65 L magnetometer and the L output coil.

An operating hint: the magnetometer assembly is installed properly when the T-magnetometer probe arrow points towards the port side, the L-magnetometer probe arrow points forward, and the V-magnetometer probe arrow points down.

P-3C aircraft equipped with the AN/ASQ-81 use three large output coils in the aft fuselage while AN/ASQ-10A configured aircraft employ a small three-coil assembly near the MAD sensor.

Experiments have been conducted at both Lockheed and Texas Instruments to determine the effect of compensating coil-generated gradients of the AN/ASQ-81 sensor. These experiments indicated that AN/ASQ-81 sensor operation is not affected by coil-generated magnetic fields of magnitude ordinarily associated with ASW aircraft. This conclusion has been substantiated by operational experience. In addition, tests conducted at Weapon System Test on a P-3C aircraft equipped with an AN/ASQ-81 MAD sensor have indicated that the large coils perform better than the small ones. Since the laboratory experiments were performed under static conditions, this difference has been attributed to the special oscillation of the detecting sensor across the variable field of the aircraft and large coil output field. This oscillation is believed to be caused by movement of the flexible boom and the shock isolators of the AN/ASQ-81 sensor.

P-3C (ASQ-10)

TERMS	AVERAGE	STANDARD DEVIATION
T	525	13
L	425	40
V	600	20
LL(1)	240	28
LV(2)	472	0
VV(3)	490	0
tt(4)	570	13
l l(5)	725	37
lv(6)	445	13
FOM	2.02 gammas	0.41 gamma

P-3C (ASQ-81)

TERMS	AVERAGE	STANDARD DEVIATION
T	525	8
L	390	26
V	590	11
lv(1)	465	7
tt(2)	555	8
LL(3)	280	5
l l(4)	725	9
v l(5)	435	15
VV(6)	490	0
FOM	1.06 gammas	0.15 gamma

Compensator Terms and Their Average Values P-3C aircraft with the AN/ASQ-10A or AN/ASQ-81 installed employ the following terms. The average values and standard deviation (a measure of how close the numbers bunch around the average) were determined for approximately 40 aircraft, each as delivered from Lockheed. These numbers are the dial setting which occur on the Control Box.

The control box settings on any aircraft should be within ± two standard deviations; if not, the compensator and aircraft wiring should be checked thoroughly.

The standard deviation is zero for the VV term since it is set at 490 for all aircraft. The procedure to compensate this term is very special and is not enjoyed by crew members. The LV term in the ASQ-10 equipped aircraft presents an additional procedure to compensate. A few compensations indicated an average dial setting of 472 for the LV term for all aircraft, with standard deviation of zero.

The average FOM values of 2.02 gammas (ASQ-10) and 1.06 gammas (ASQ-81) for each aircraft appear reasonable when compared to NATOPS maximum values of 2.5 and 1.25 gammas.

GENERAL DISCUSSION OF MAD COMPENSATION Leliak derived the maneuver noise signals by employing a mathematical model, but understanding his presentation requires that the reader have a sophisticated knowledge of mathematics; however, a simplified explanation of these signals can be obtained by reducing the earth's magnetic field into components.

This simplified explanation will be illustrated by doing a simulated compensation of the P-3C with an AN/ASQ-81 installation for dip angles above 45° North or South, supplemented by a few of the terms from a P-3C with an AN/ASQ-10A installation. This exercise is not to be construed as a substitute for published fleet compensation procedures. It is suggested that, in addition to following the diagrams, the examples be checked by frequent inspections of entries in Tables 2 and 3. Also, the reader is invited to provide additional examples to determine entries that are not illustrated because of lack of time and space. A compensation chart is contained in Table 6 and the steps can be checked off as compensation proceeds.

The examples of compensation are for the case with which we are most familiar; namely, in the vicinity of 60° magnetic North where there are both a horizontal and vertical component of the earth's field. We would normally start a compensation with the last control box dial settings for the aircraft, the squadron average, or those average values mentioned earlier in this article.

The compensation always commences with a North or South roll because the P-3C has only one significant fundamental term - the T perm - which is manifested by this maneuver, although there can

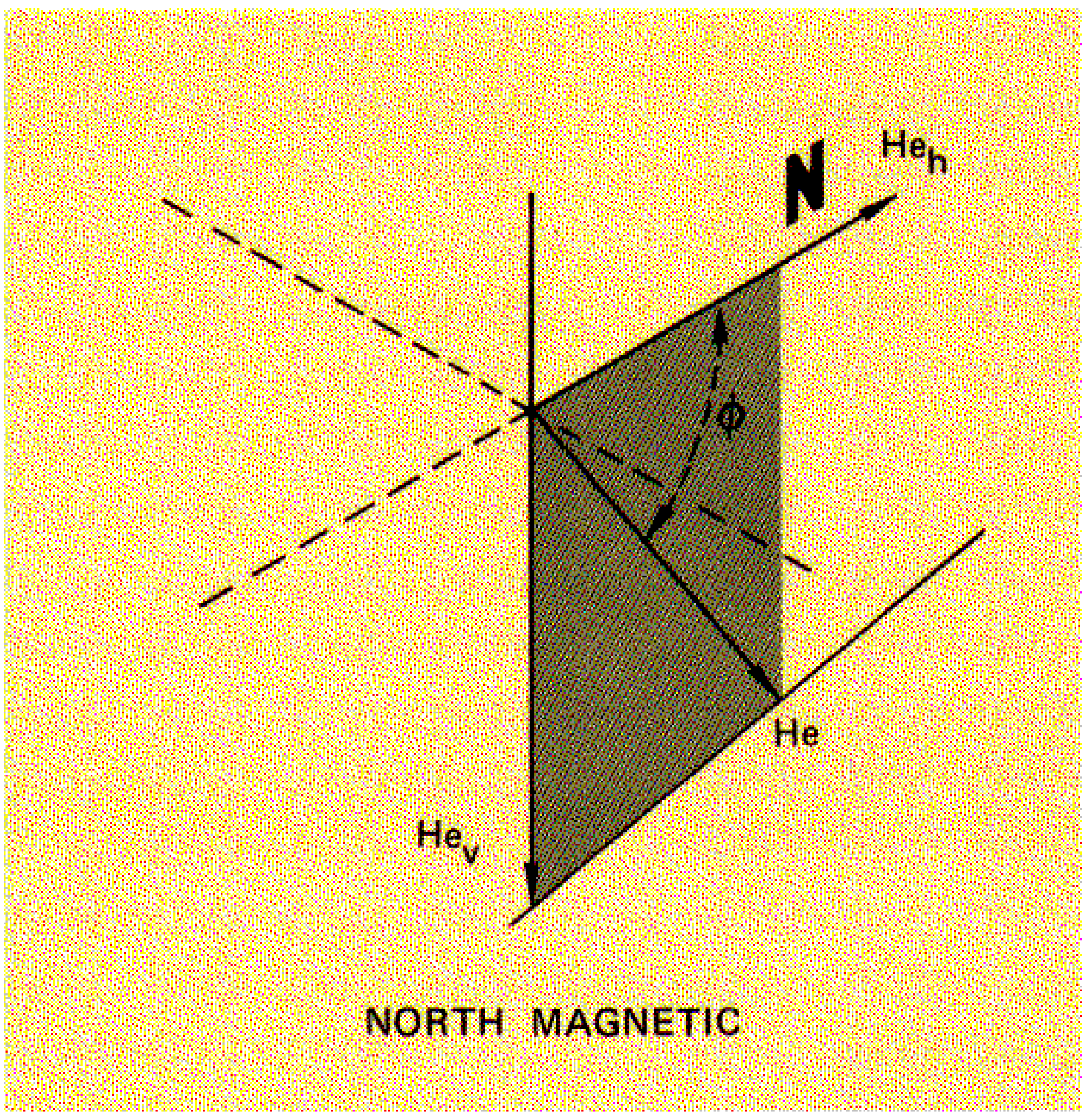


Figure 10. Earth's Magnetic Field Components

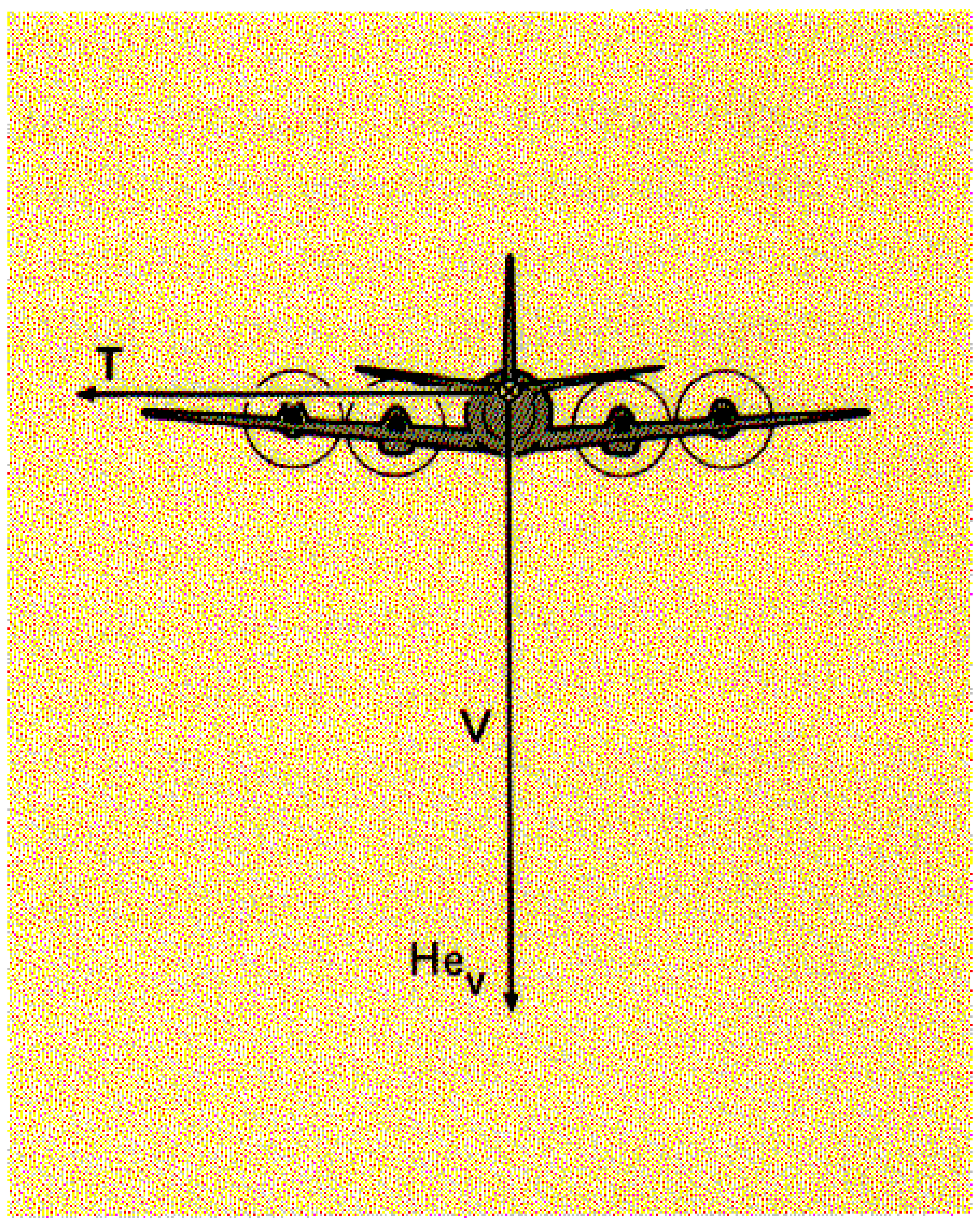


Figure 11. T and V Aircraft Field

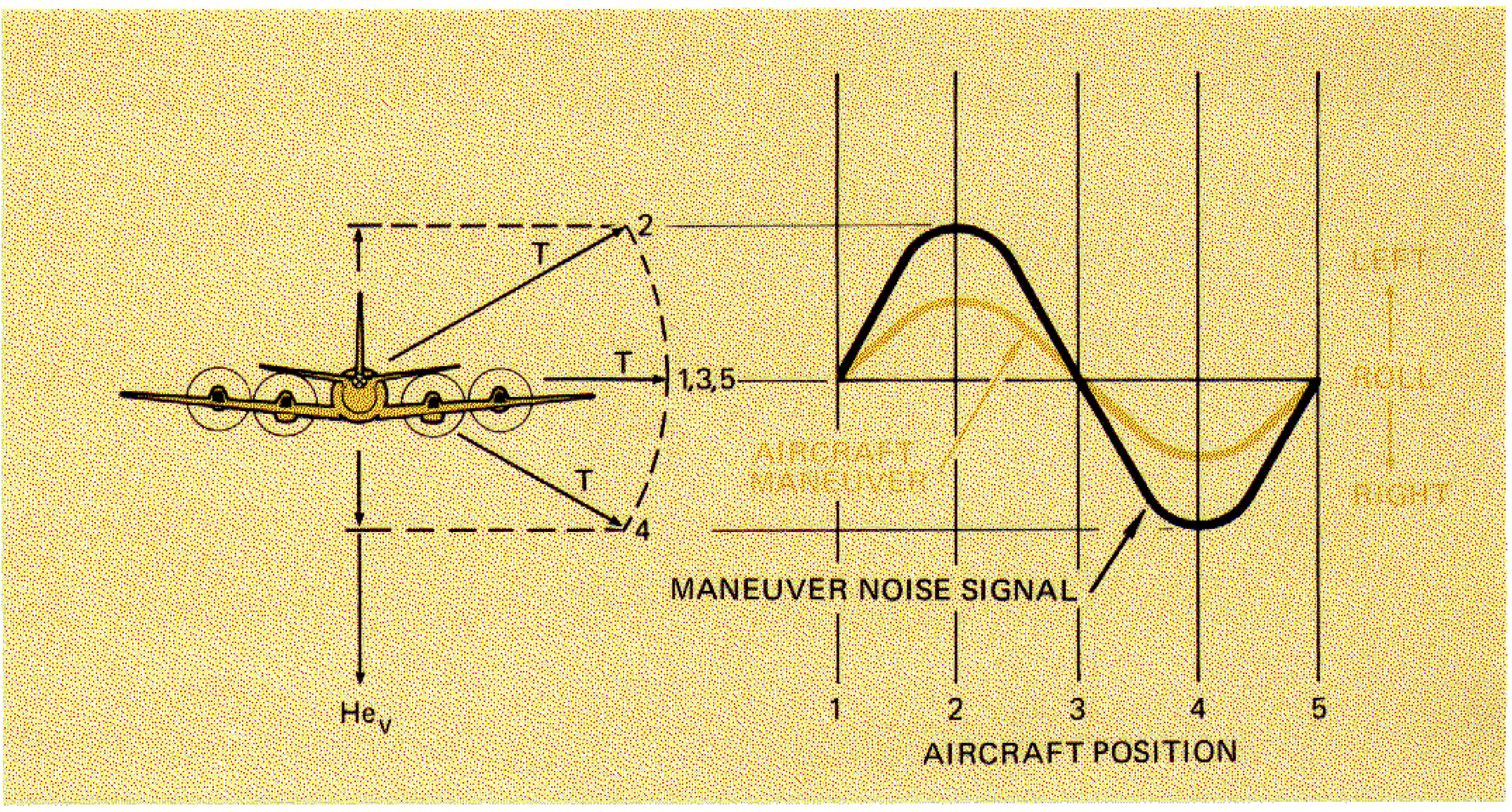


Figure 12a. T-Term Signals

Table 6. ASQ-81 Compensation Chart

FULL TRIM COMPENSATION				
TERM	MAN	+/– HEADING	NUMBER	EXTRA SPACES
VV (6)				
T	⊖	N +		
		S +		
L	⊕	E +		
		W +		
Iv (1)	⊕	E +		
		W +		
ALT. COMP.	⦶			
		E or W		
V	⊖	E +		
		W +		
tt (2)	⊖	E +		
		W –		
Recheck T; Recomp if necessary				
LL (3)	⦶	N +		
		S –		
I I (4)	⦶	N +		
		S –		
vl (5)	⦶	N +		

LEGEND:

⊖ = ROLL ⊕ = YAW ⦶ = PITCH

NOTE:

The plus and minus signs following the magnetic headings are the sense settings for the compensator servo sensing.

AIRCRAFT

LAC NO. : ____________

SERNO : ____________

FLIGHT : ____________

DATE

____

____

NAME

____

____

FIGURE OF MERIT				
HDG	⦶	⊖	⊕	S/L
N				
S				
E				
W				
TOTAL	+	+	=	

be a second harmonic component from an uncompensated V term.

In order to illustrate the above, the earth's magnetic field (He) is decomposed into horizontal and vertical components denoted as He_h and He_V. (See Figure 10.)

If we look into the tail of the aircraft as shown in Figure 11, we see that the aircraft perm field vectors T and V are both perpendicular to the earth's horizontal component. Hence there is no projection of these fields along the horizontal field in a pure roll. However, there is a time variation of the projections along the earth's *vertical*

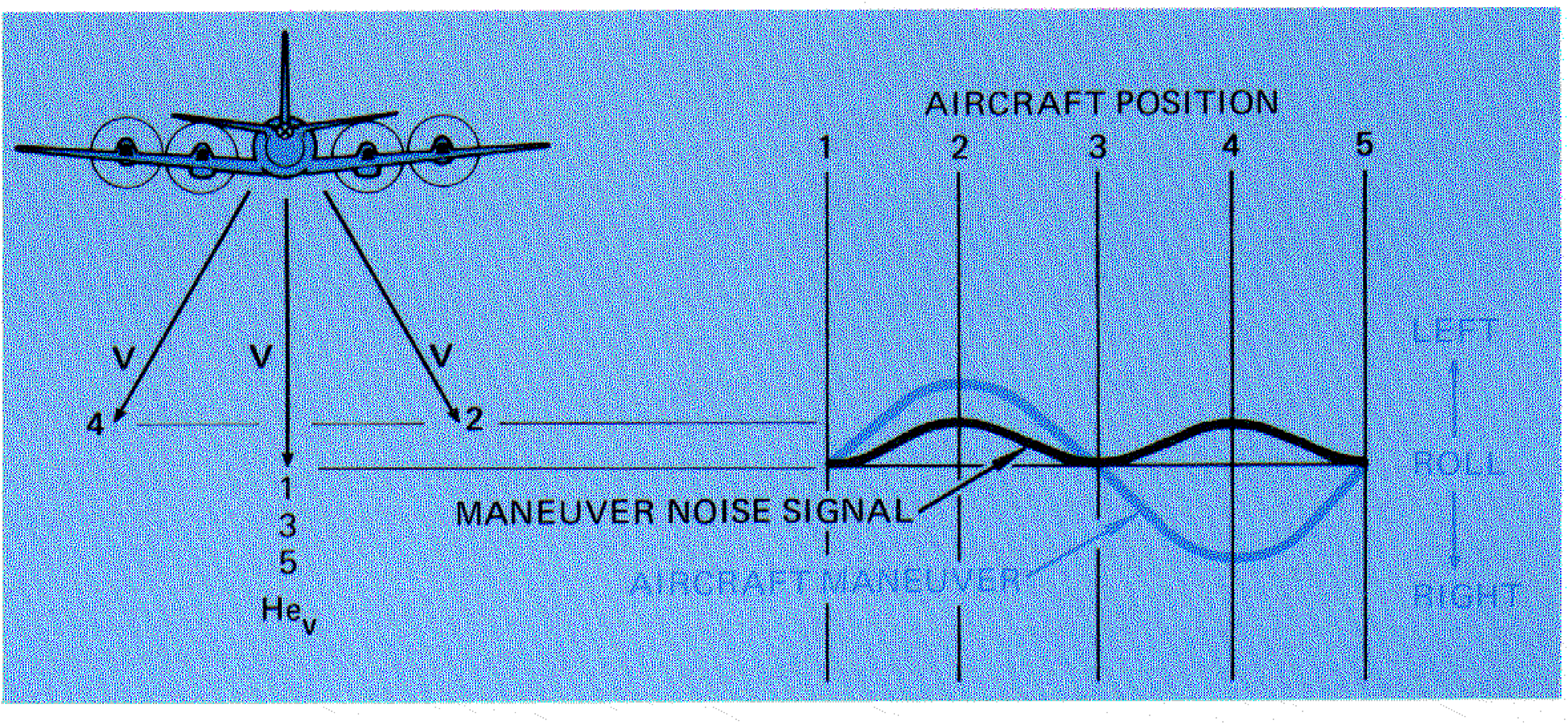


Figure 12b.
V-Term Signals

field due to the maneuver, which the MAD sensor detects as a maneuver noise signal.

This process can be explained while examining Figure 12a. As the wings are level (1), the projection of T perm is zero on the V earth's field. With a right wing up (2), the projection builds to a maximum in phase with the maneuver returning to zero as the wings are level again (3). As the wing proceeds to a full left wing down (4), the signal goes a maximum in the other direction. A time diagram to the right of the figure shows the sinusoidal pattern that is generated which is in phase with the maneuver signal.

During these maneuvers the V perm term is also generating a signal. Figure 12b shows that when the wings are level (1), V has a maximum projection along the earth's vertical field.

As the plane rolls with the right wing down (2), the V perm projection is reduced and then returns to a maximum as the wings are leveled (3). The V perm is reduced again as the wings roll down to the left (4), and returns to maximum as the wings are level again (5). A careful plot of the time variation of this projection along the earth's vertical magnetic field shows it to be twice the maneuver frequency. See Figure 12b.

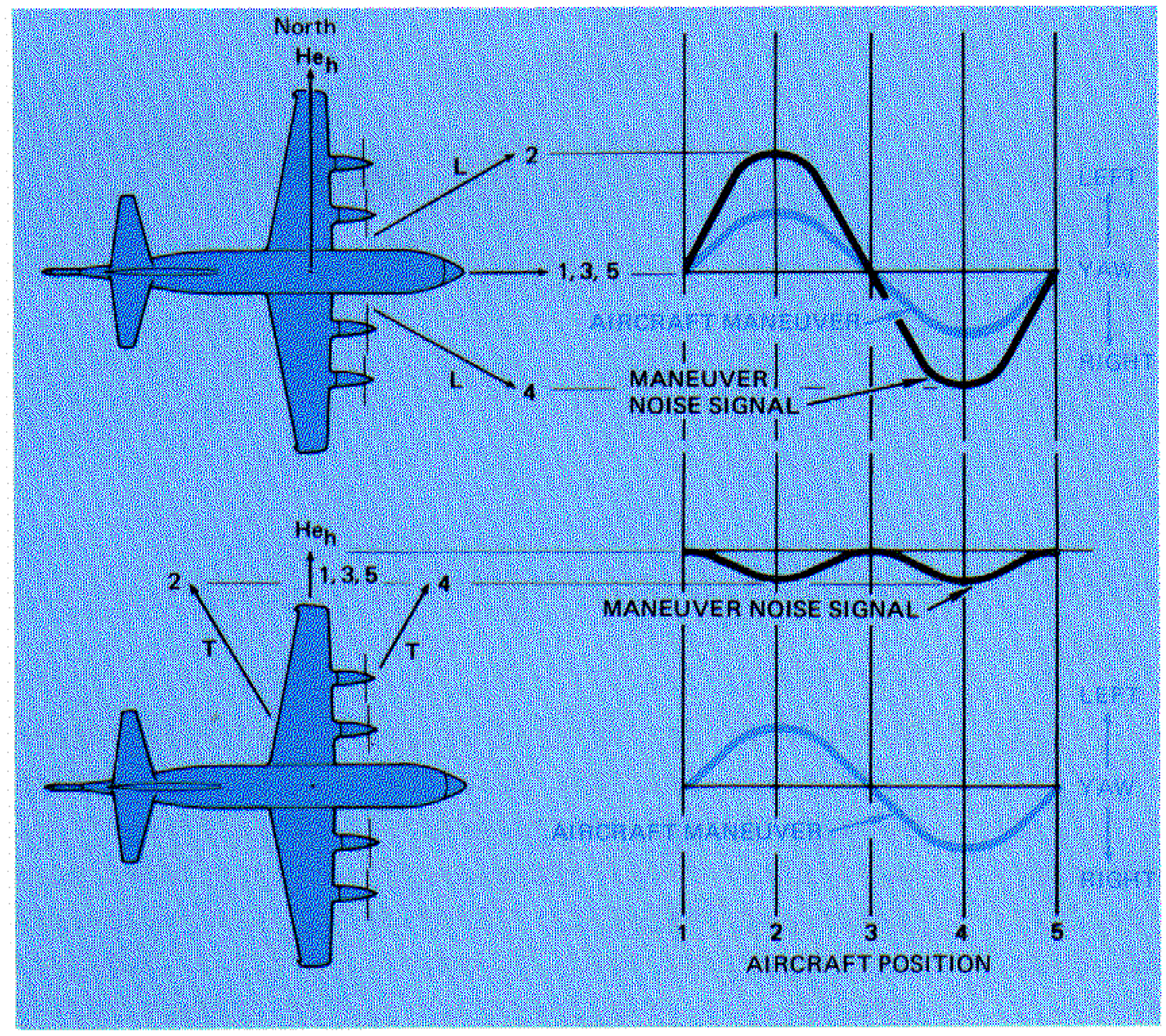


Figure 13a. L-Term Signals

Before we continue, let us make some observations. An uncompensated T or V perm term will give a fundamental signal for T and a second harmonic signal for V on any heading for roll maneuvers. These terms are independent of heading because they are generated by their projections along the earth's vertical magnetic field. Also note that the L perm term cannot ever generate a signal on any roll maneuver. We now compensate the T term by setting its potentiometer to the average T control box reading for North and South.

Next, we turn to an East or West heading and commence a yaw. Assuming the heading is East, inspection of the aircraft plan view in Figure 13a shows that the L and T (uncompensated) perm terms cause a fundamental and second harmonic signal respectively on East-West yaws similar to the signals of the T and V perm terms on North and South rolls. However, the L and T perm terms cause time variation along the *horizontal* projection of the earth's magnetic field. We see that the L perm term will generate an in-phase fundamental signal with the aircraft yaw maneuver. The uncompensated T term also would generate a second harmonic signal by its projection against the earth's horizontal field, but the previous roll on North and South should have eliminated this signal. The V perm term will generate no signal since the aircraft is yawing around it as pivot. Although it is not part of the compensation procedure, it is interesting to note that with yaws on North-South headings, the roles of T and V perms are reversed; i.e., the T term generates the fundamental signal and the L term generates the second harmonic.

In addition to compensating L perm on East-West headings, the eddy current lv is compensated. Since its signal is 90% of out-of-time phase with the L term, the AN/ASA-65 correlator helps separate the signals. As the L perm in-phase signal is reduced, the counters will tend to oscillate due to the eddy-current term; thus, one switches back and forth until the composite signal is a minimum. (Eddy-current terms generation will be discussed later in this article.)

For dip angles above 45°, an inspection of Tables 2 and 3 shows that the pitch signal for L is larger than yaw signals on East-West headings ($\sin\phi > \cos\phi$ for $45^\circ < \phi \leq 90^\circ$), so one could ask why not use pitches instead of yaws. However, we remember that the earth's vertical magnetic field gradient introduces a pitch signal. With the AN/ASQ-10A

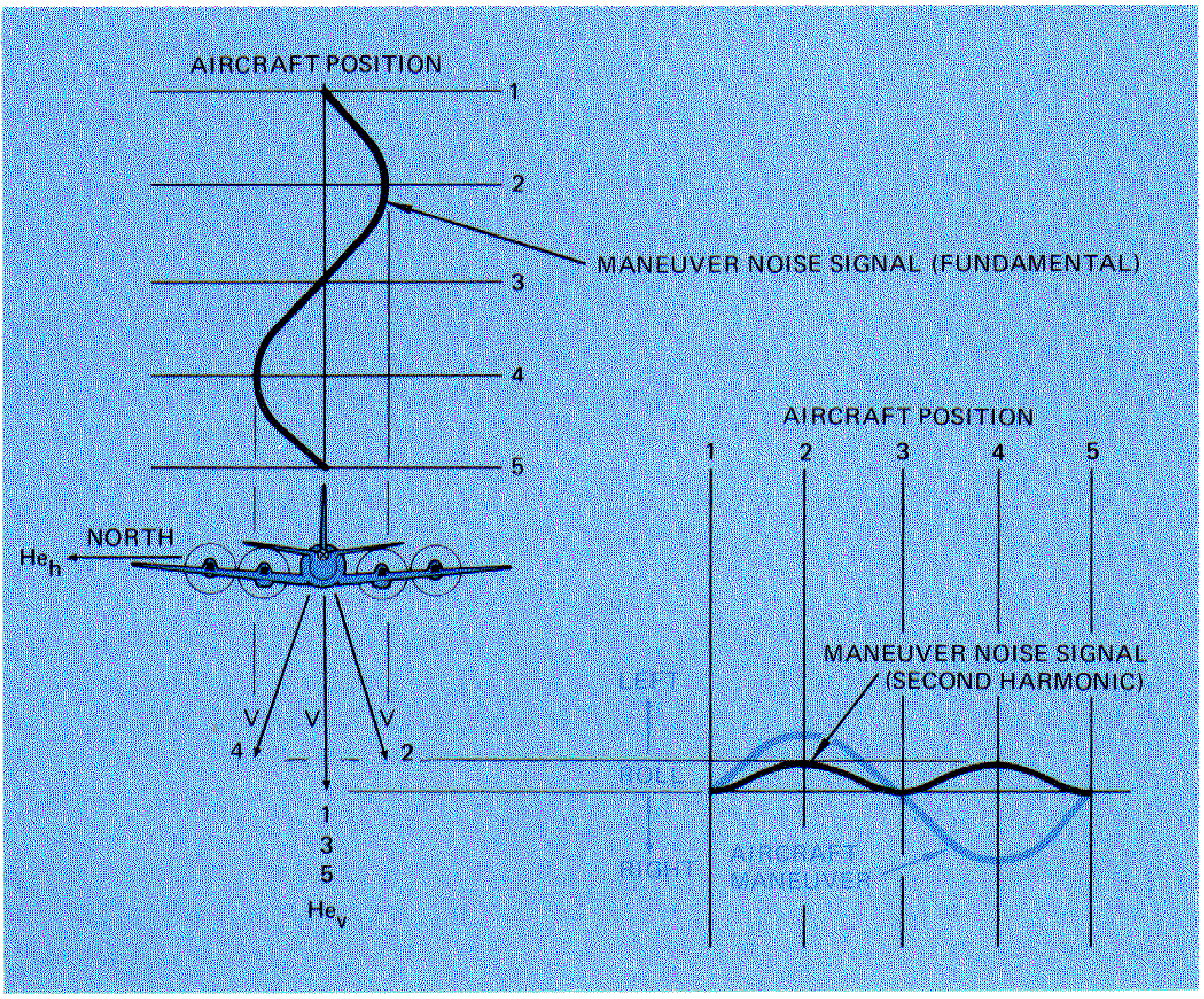


Figure 14. V-Term Signals

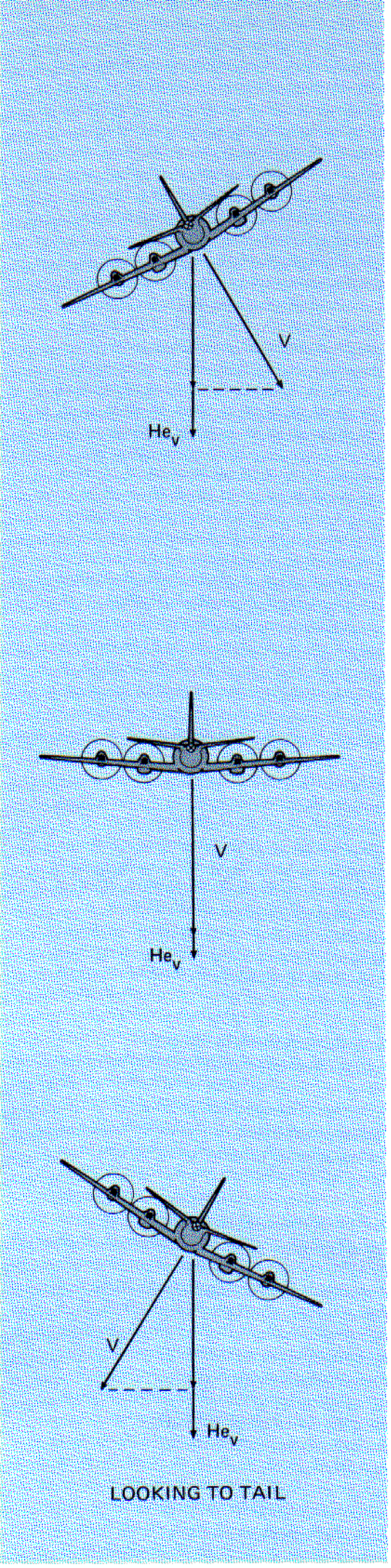


Figure 15a. Induced Vertical Component V

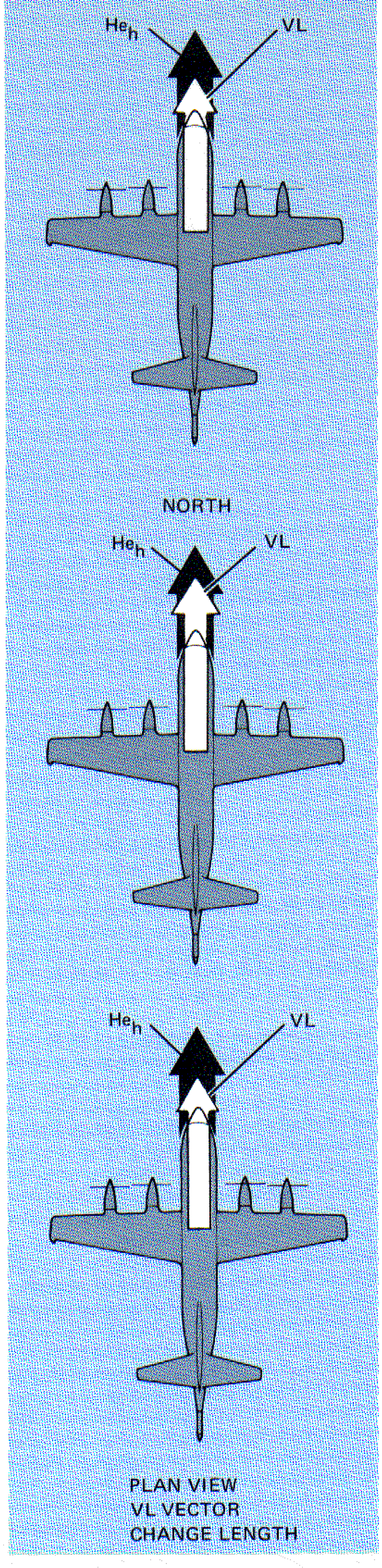


Figure 15b. LV-Term Signals

system, we do employ an East-West pitch to compensate L and the vertical earth's field gradient. However, we pay a penalty by having a non-optimum value for L which gives an uncompensated signal in East-West yaws.

The AN/ASQ-81 system has an altitude compensator to reduce the vertical field gradient. After yaws, pitch maneuvers are performed on East-West headings in order to set the altitude compensator.

The altitude compensator uses a form of barometric altimeter. A bellows inside the altimeter operates around a neutral position in a linear range of ± 200 feet. After large changes of altitude such as 10,000 feet, it requires 12 to 15 minutes before the bellows returns to its neutral position. Large changes of altitude in low altitude localization patterns also may render it inoperative. Altitude compensations during flights over the sea are performed at altitudes of approximately 10,000 feet to reduce background noise. Since the air is denser at lower altitudes and the altitude compensator operates on a differential pressure, the compensator setting required at tactical altitude is much lower than that obtained at high altitudes. The altitude compensation values obtained at 10,000 feet should be multiplied by 0.75 for use during operations at MAD trapping altitudes of 300 - 500 feet. The altitude compensator potentiometer is adjusted on East or West pitches until the noise signal is reduced to a minimum.

In a manner similar to L and lv, the terms V and -tt are compensated on East-West rolls. As was noted before, an uncompensated V term will generate a second harmonic on any heading. However, on an East or West heading the V vector is perpendicular to the horizontal component of the earth's magnetic field and will generate a fundamental signal at its maximum value. (See Figure 14.)

For both the AN/ASQ-81 and AN/ASQ-10A installations, we normally compensate for the induced term -LL with North and South pitches. However, it is much easier to explain induced terms if we start by illustrating the VL + LV term on North or South rolls. (Induced term compensation is illustrated by Figures 15 through 17.)

The P-3C equipped with the AN/ASQ-10A system has an LV term which does not exist in P-3C aircraft equipped with the AN/ASQ-81 system. This term is caused by the asymmetrical servo in the ASQ-10A detector. (The compensator compensates not only the aircraft but also the compensator, and in this case the MAD detector. However, we have a long way to go before we can lay claim to really compensate the AN/ASQ-81 Detector.)

In a North or South roll, the LV induced term is easy to visualize. (See Figure 15a.) The earth's horizontal field is a constant along the longitudinal axis of the aircraft. This induces a constant field along the longitudinal axis of the aircraft which appears to be a magnet with an axis along that of the aircraft. A vertical component of this magnet's field crosses the MAD sensor head located in the boom. This vertical component is of fixed magnitude with respect to the sensor. Thus, in this case, the LV term appears to behave as though it were a permanent vertical magnetic field, V.

Another characteristic of induced terms is that the output polarity is reversed when the North or South heading is reversed (the second harmonic signals are 180° out of time phase). When the aircraft heading is reversed, the earth's horizontal field (which remains the same) reverses the direction of the induced field with respect to aircraft coordinates. The AN/ASA-65 magnetometer probe, which is fixed to the aircraft frame and is employed as the driving function for compensation, also senses the reversal of the induced field.

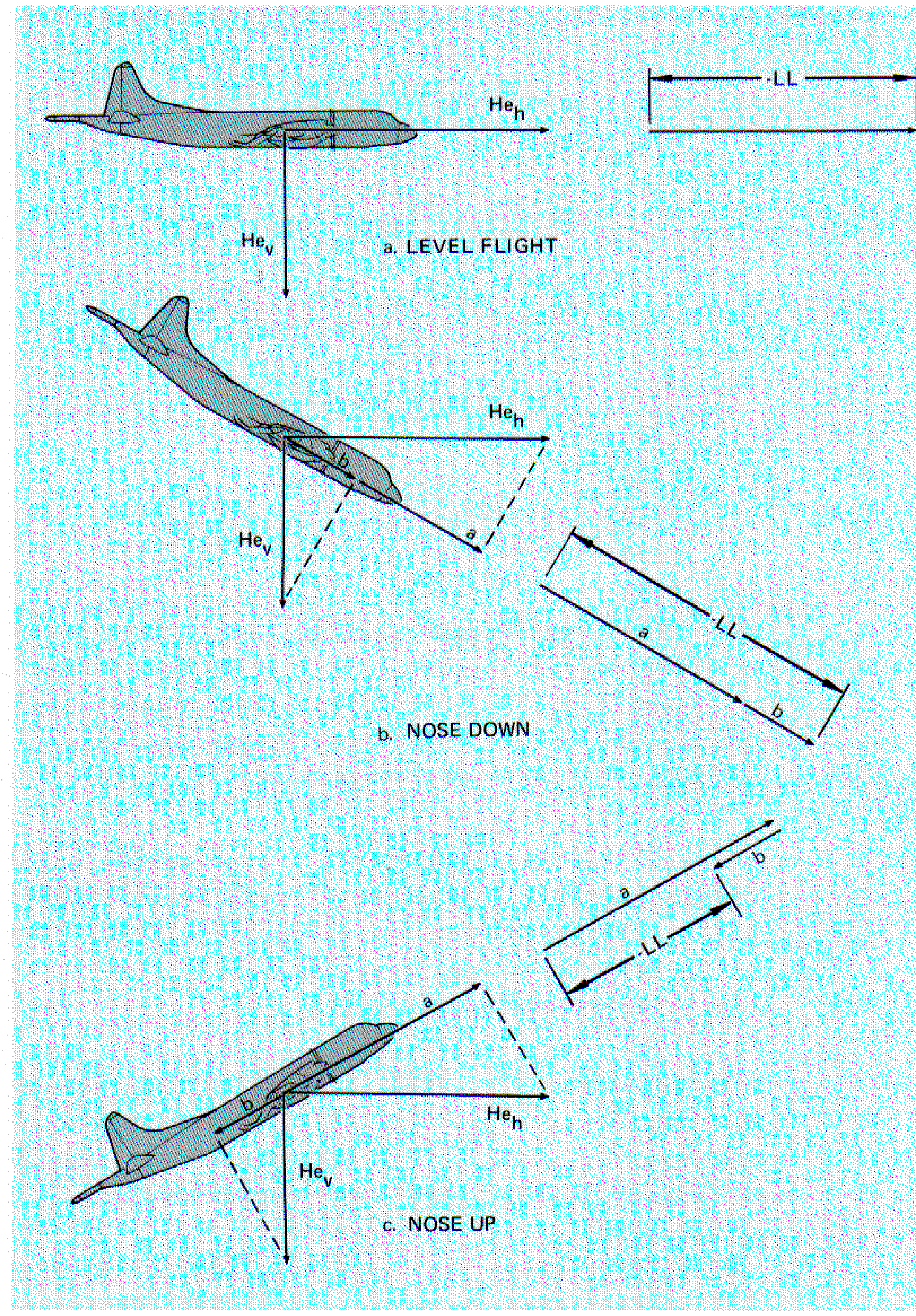
As was stated earlier, the LV and VL terms behave the same. We will use the special case of the North-South roll to illustrate this phenomenon. The VL term vector, representing the resultant field induced along the aircraft's vertical axis by the earth's magnetic field, is pointed along the longitudinal axis of the aircraft. (See Figure 15b.) In this case the VL vector is aligned with the earth's horizontal field. Since the aircraft is maneuvering around the VL vector as an axis, the VL vector is parallel to the earth's horizontal field component and perpendicular to the earth's vertical field vector, the question arises - how can the VL term generate a signal? The answer is that the magnitude of the VL vector, unlike permanent field vectors, is changing. In this case, as the aircraft rolls North-South, the earth's vertical field component along the aircraft vertical axis changes. Hence, the resultant of the vertical induced field along the longitudinal axis of the aircraft changes in magnitude.

Since the aircraft axis and VL are aligned with the earth's horizontal field component, a signal is generated; i.e., there is a time variation of the earth's horizontal field component which the MAD equipment detects as a second harmonic signal. This is illustrated in Figure 15b.

Leliak has shown that both the LV and VL terms will give the same magnitude signals; hence both terms can be treated as one term by the compensator. Although the LV term is not compensated by North-South roll maneuvers, the preceding explanation illustrates a characteristic of the induced terms, namely, that they change in magnitude.

Compensation of -LL is performed during a pitch maneuver on a North heading as shown in Figure 16. The -LL field is induced along the aircraft's longitudinal axis by the horizontal and vertical components of the earth's magnetic field.

Figure 16. -LL Term Components



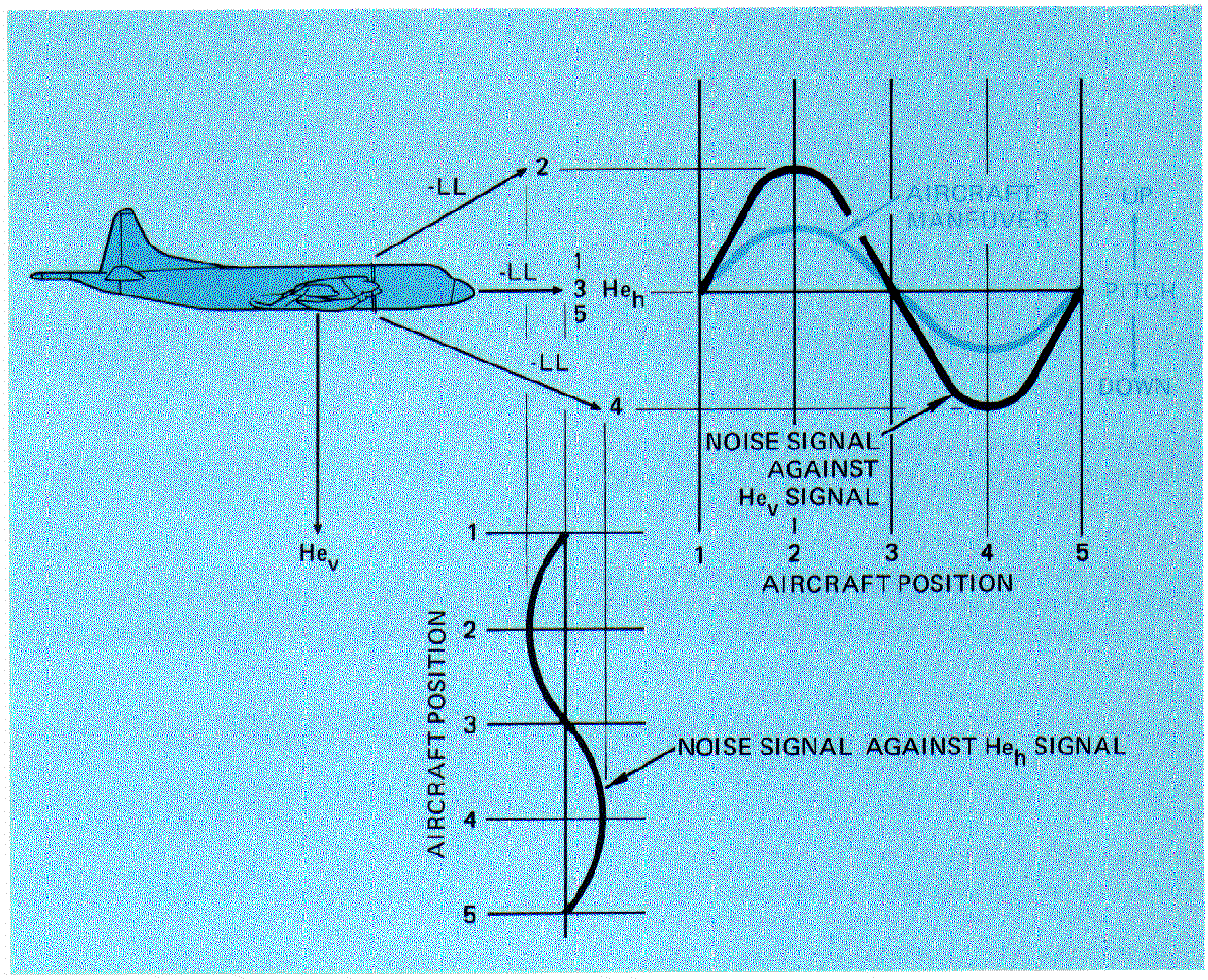


Figure 17. Composite -LL Term Signals

As the aircraft maneuvers, this induced field changes both in magnitude and in its orientation to the earth's field. Tables 2 and 3 show that fundamental and second harmonic signals are generated as shown in Figure 17.

In addition to compensation of -LL on North-South pitches, the -ll eddy current is compensated at this time. Since -ll is 90° out of phase with the -LL signal, it is removed by use of the AN/ASA-65 correlator servo.

To illustrate the eddy-current terms, we will use the vl eddy current term as an example and draw comparisons with compensation for the LV and VL induced terms.

An inspection of Figure 18 will illustrate how the vl eddy-current term is generated during roll maneuver. As for the VL term, the earth's vertical component projects along the vertical axis of the aircraft, developing a second harmonic signal v as illustrated in Figure 18a. In Figure 18b this signal is differentiated with respect to time; i.e., the slope of Figure 18a is plotted in Figure 18b with respect to time which is 90° out of phase. This signal causes a magnetic field along the longitudinal axis of the aircraft of a variable length vl (Figure 18c) which is detected as a time variation along the horizontal axis of the earth's magnetic field. With induced terms, we saw that LV and VL behaved the same for all maneuvers. However, on a North roll the horizontal component of earth's field has a constant magnitude with respect to time along the longitudinal axis of the aircraft; hence, the time derivative of this signal is zero. Therefore, the cross terms vl and lv must be handled separately by the compensator.

Actual compensation of the vl term is performed with a pitch maneuver. Space limitations prevent us from describing or illustrating this procedure, but the reader may refer to Tables 2 and 3 for the fundamental and second harmonic signal coefficients for vl.

As was mentioned previously, the determination of induced VV takes a special procedure. Tables 2 and 3 show that V and VV are compensated together by means of the V term together on East-West rolls. Since the magnitude of the V term signal has a different dependency on dip angle than the VV term, the aircraft will be out of compensation if the aircraft proceeds to a distant operating area. In order to compensate the VV term, a trim to zero or trial and error method is employed by making standard roll maneuvers during a standard rate turn. This maneuver is usually accomplished manually by the pilot, but it has not been popular. However, this problem is avoided by setting the VV term control box dial to 490.

A special procedure *can* be employed for determining the LV term for the AN/ASQ-10A. However, the present practice of using 472 as the setting is employed. ▲▲

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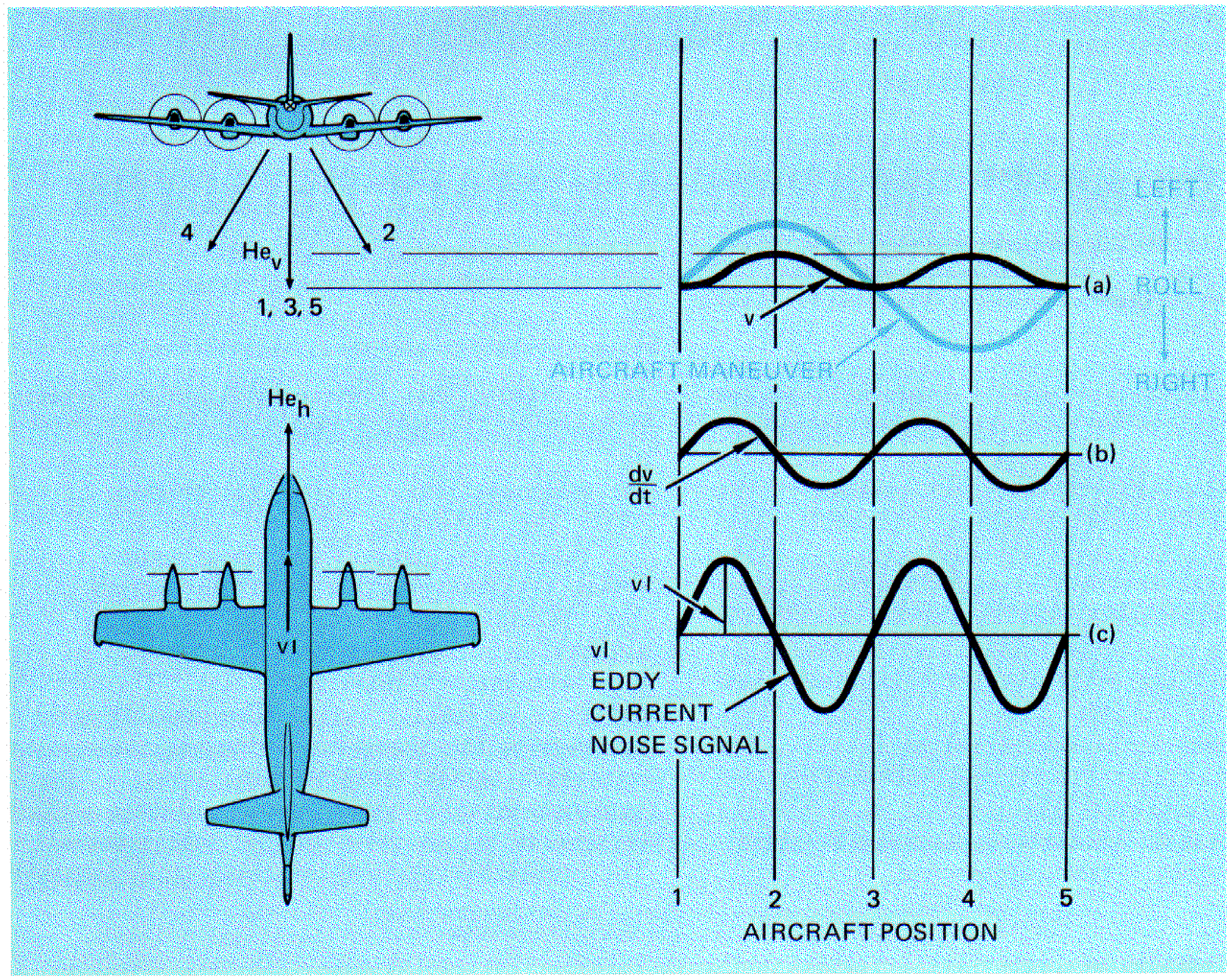
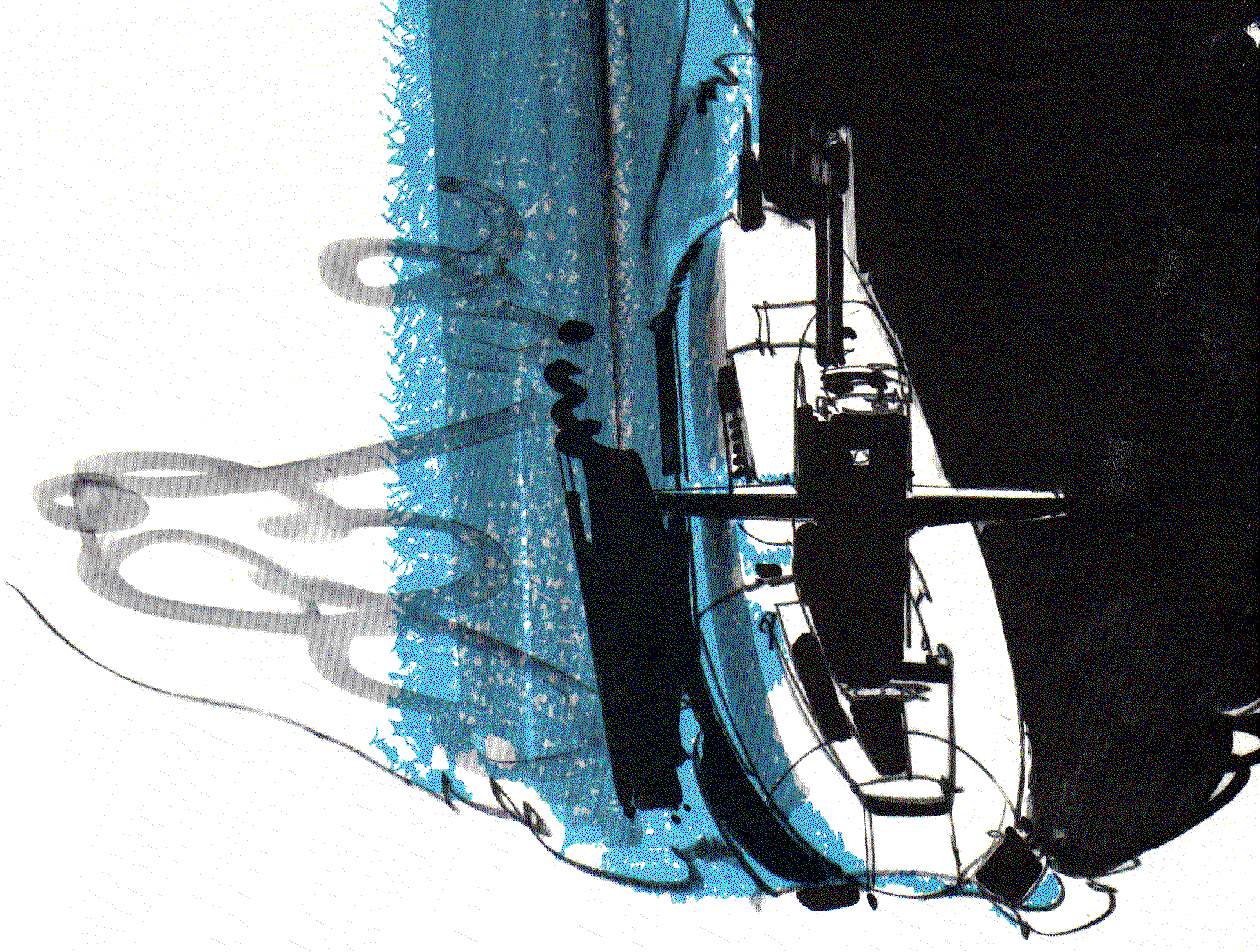
Figure 18. vl-Eddy Current Term Signals





AN/ASA-64 SUBMARINE ANOMALY DETECTOR

by B.A. BOLLENBACH, Electronics Engineer
Magnetic Branch, Electro-Optics Development Division,
U. S. Naval Air Development Center, Warminster, Pennsylvania

The AN/ASA-64 Submarine Anomaly Detector (SAD), developed by CAE Electronics Ltd, complements the P-3 Magnetic Anomaly Detector system. The SAD automatically marks, in the presence of aircraft maneuver and geologic background noise, submarine signals generated by the AN/ASQ-10 or AN/ASQ-81 magnetometers. When a SAD recognition occurs, the MAD operator is alerted by a tone in the ICS so that he can verify the contact. The SAD places a recognition mark on the RO-32 recorder paper tape that is coincident with the suspected submarine signal. After inspecting the signal, the operator can accept the recognition mark as a valid contact by depressing the "MAD accept" button on his console, validating the recognition mark occurrence.

DESCRIPTION The Submarine Anomaly Detector is functionally divided into a recognition channel and an inhibition channel. Magnetometer signals are processed through the recognition channel while the inhibition channel monitors aircraft roll maneuvers. Aircraft maneuver signals require special processing so that submarine signals can be discriminated from them. The submarine signal appears, primarily, against a background of geologic and aircraft maneuver noise. Through the processes of band rejection filtering and periodic integration, the recognition channel can separate submarine signals from geologic noise. Aircraft maneuver noise, however, requires additional effort because of its similarity to the submarine signal. The inhibition channel processes roll maneuver information, which looks like submarine signals, to effect recognition mark suppression during maneuver events. The inhibition channel operates in an aircraft magnetic environment exhibiting FOM's ranging up to 2.5 gammas. If the FOM exceeds 2.5 gammas, readjustment of the inhibition channel may be required in order to maintain maneuver false alarms below an acceptable level. Since this is a bench adjustment, a better approach is to lower the FOM of the aircraft.

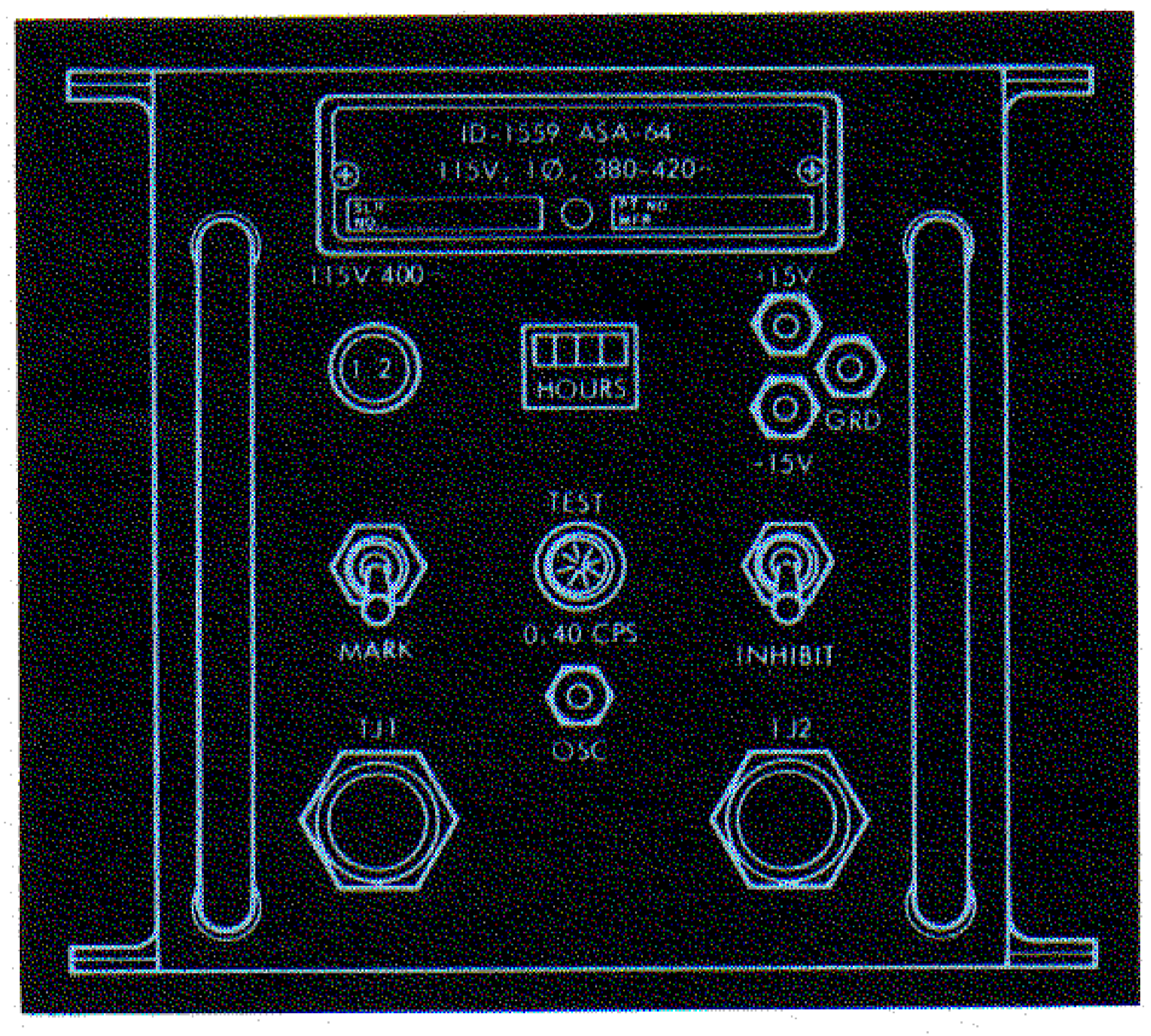
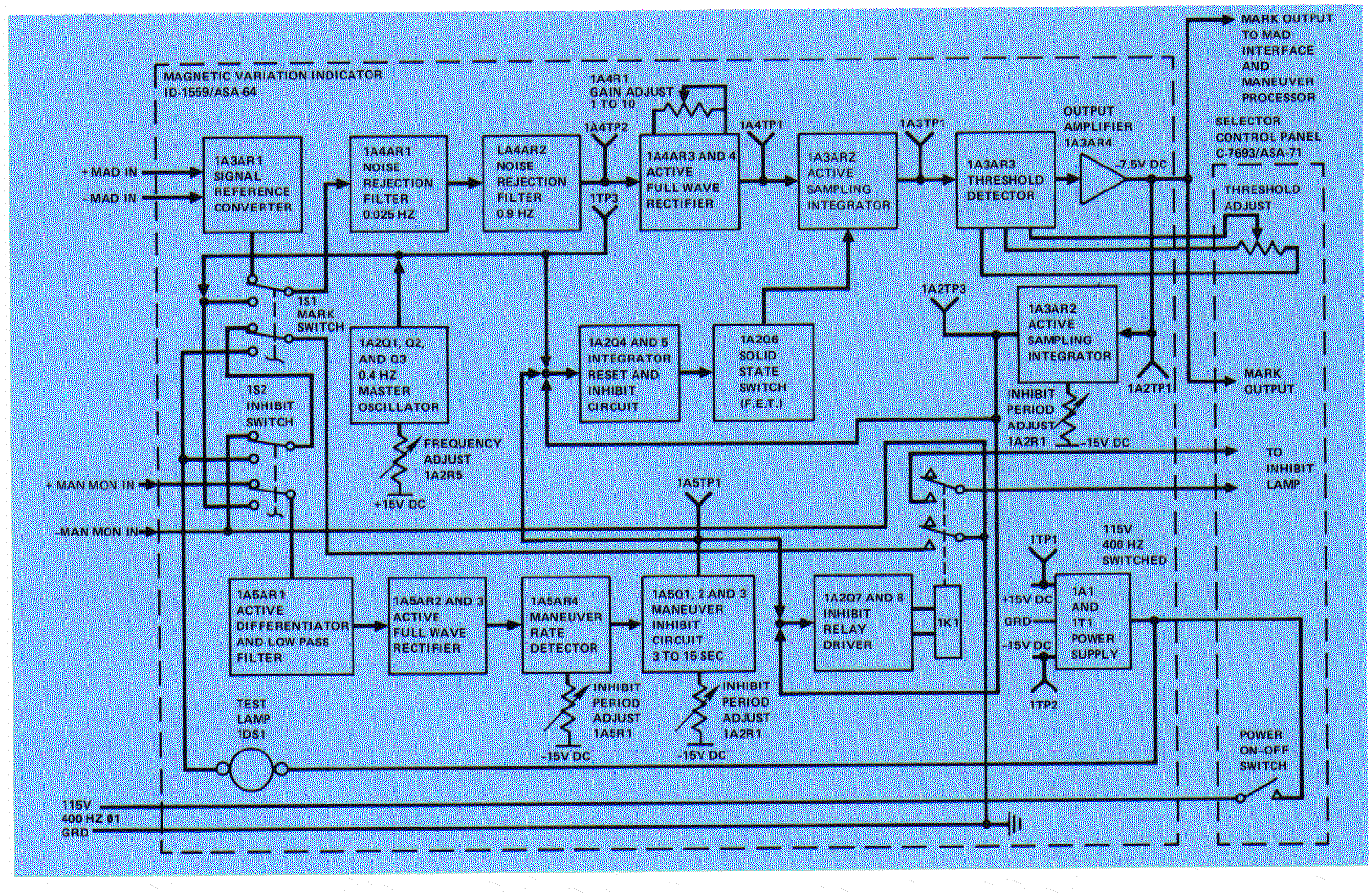


Figure 1. AN/ASA-64 Indicator Control Panel and SAD Group Block Diagram



MAGNETOMETER SIGNALS Magnetometer signals enter the recognition channel through a buffer amplifier and then pass through two band-rejection filters centered at 0.025 Hz and 0.9 Hz. (See Figure 1.) The filters achieve signal-to-noise enhancement by attenuating signal energy that is predominately associated with geologic noise. Next, the signal is full-wave rectified to preclude signal loss due to area cancellation in the following stage, the periodic integrator. The integrator performs cyclically, being reset to zero every 2.5 seconds. During the integration period, the integrator output is instantaneously proportional to the accumulated area of the full-wave rectified signal. The integrator output is impressed upon a voltage threshold circuit. The threshold level is selected by the operator on the basis of geologic noise levels observed on the RO-32 recorder. (Table 1 displays recommended threshold levels as a function of geologic noise.) Signals that exceed the threshold are amplified by the output stage and become recognition marks.

Table 1. Recognition Threshold Voltage

NOISE RO-32 RECORDER	1.5 TO 2.0 MAJOR DIV.	2.5 TO 4.0 MAJOR DIV.	4.0 TO 5.0 MAJOR DIV.
THRESHOLD VOLTAGE AN/ASA-71	2.5 TO 3.0 VOLTS	5.0 TO 6.5 VOLTS	6.0 TO 7.0 VOLTS

AIRCRAFT ROLL MANEUVER SIGNALS Aircraft roll maneuver signals are processed by the inhibition channel to obtain the maneuver rate. Recognition channel suppression is initiated when this rate exceeds a preset limit. As the rate falls below the limit, suppression continues for a short fixed period of time (nominally, 5 seconds). If, within this time period, a recognition mark would have occurred, recognition channel suppression is continued for an additional period. This process continues until no recognition mark would have appeared during the last suppression period.

Additionally, the inhibition channel suppresses multiple recognition marks. After the occurrence of a recognition mark (the inhibition channel is triggered by the trailing edge of a recognition mark), the suppression cycle is initiated. If a second mark would have occurred within the suppression period, the period is extended, and so on.

Aircraft roll maneuver signals from the inertial system are transmitted through a synchro repeater to the AN/ASA-71 where they are phase detected and provided as an input to the SAD inhibition channel. The roll signal, a voltage proportional to the aircraft roll position, is passed through a band-limited differentiator to obtain the aircraft roll rate. (See Figure 1.) The differentiator output is full-wave rectified and impressed on a voltage threshold circuit. (This threshold level is internally adjusted to correspond to a roll rate of 25 deg/sec.) That portion of the roll rate signal which exceeds the threshold appears as a voltage at the threshold circuit output to turn on the flip-flop. The activated flip-flop causes the recognition channel to be suppressed by shunting recognition signals to ground through a transistor switch just before they reach the output stage. Coincidentally, the flip-flop sets the timer so that it will start timing when it is triggered, respectively, by the inhibition and recognition channel threshold circuits. Timing begins when the roll rate falls below the maneuver rate threshold level. The timer, after a preset interval, switches the flip-flop off unless the timer is reset by an input from the recognition channel threshold detector. Suppression of multiple recognition marks is accomplished in an identical manner except that the suppression sequence is initiated by the trailing edge of a recognition mark.

The Submarine Anomaly Detector can be a significant aid to the Sensor Station 3 operator. Better time and position accuracy is provided by an automatic MAD mark capability giving the operator additional confidence as well as relief from the stress created by continual monitoring of the MAD signal. The SAD recognition capability is comparable to that of the average human operator provided the aircraft FOM is within acceptable limits and the recognition threshold voltage has been properly selected on the basis of ambient geologic background noise in the operating area. ▲▲

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