Engineering Notes

ENGINEERING NOTES are short manuscripts describing new developments or important results of a preliminary nature. These Notes cannot exceed 6 manuscript pages and 3 figures; a page of text may be substituted for a figure and vice versa. After informal review by the editors, they may be published within a few months of the date of receipt. Style requirements are the same as for regular contributions (see inside back cover).

Canadian Helicopter Inboard Magnetic Anomaly Detection Evaluation

A. K. Honig*
Canadian Air Force, Shearwater, Nova Scotia

Study of Platform Suitability

Magnetic fields of helicopter

THE success of any inboard magnetic anomaly detection (MAD) system depends on the degree to which the interfering magnetic fields and associated field gradients of the platform can be compensated at the magnetometer. To determine the magnitude of the magnetic fields and field gradients of the CHSS-2 helicopter, a magnetic survey of CHSS-2 No. 4003 was undertaken at Shearwater by Experimental Squadron Ten (VX-10). The detailed results of these measurements are contained in the Ref. 1. It was encouraging to note that the value for the equivalent magnetic moment calculated from the field measurements for the CHSS-2 was 270,000 gamma ft^3 acting at a point 3 ft below and 1 ft forward of the main rotor head of the helicopter. ($M = Hr^3/2$ where H is in gamma and r in feet). This compared very favorably with the value of 500,000 gamma ft^3 obtained for the HO4S helicopter by the National Aeronautical Establishment (NAE). It was concluded from the survey that the CHSS-2 helicopter could provide a suitable platform for MAD, and a trial installation was recommended.

Location of magnetometer

The location for the magnetometer was determined from the magnetic field plots from the helicopter survey, and simultaneously governed by practical considerations such as armament stores trajectories and the dipping sonar. The main points of concern were 1) the total field intensities, 2) field gradients, especially in planes of high vibration, and 3) local field distortions about the magnetometer which would make compensation difficult. Also, to keep the magnitude of the interfering fields produced by eddy currents in the aircraft skin as low as possible, it was decided to position the magnetometer at least 10 ft from the hull of the helicopter. When all these factors had been considered, the best available position for the magnetometer was approximately 10 ft below the hull of the aircraft, and 10 ft aft of the tailwheel.

Boom Development

Boom design

The contract for the development of a suitable boom that would position the magnetometer as specified by VX-10 was awarded to United Aircraft of Canada Ltd. (UACL). Furthermore, because of the noise that would be generated if the magnetometer moved excessively through the field gradients of the helicopter, a vibration limit of ± 4 in. was specified. UACL set out to design a boom that would be aerodynamically stable, free of magnetic inclusions, and move the magnetometer no more than $\pm\frac{1}{2}$ in. with respect to the aircraft.

Presented as Paper 68-487 at the AIAA 3rd Marine Systems and ASW Meeting, San Diego, Calif., April 29–May 1, 1968; submitted April 25, 1968; revision received September 16, 1968.
* Captain, Experimental Squadron Ten.

The resulting boom was manufactured from 0.18-in.-thick fiberglass, and in the shape of an A-frame. The members of the A-frame were of elliptical cross section 9.2 × 2.75 in. The boom is mechanically and manually raised and lowered by a winch from within the helicopter. There is no doubt that the boom was overdesigned for stability, as it weighs 160 lb.

Ground and flight testing of boom

The boom was subjected to a series of tests at UACL to determine its frequency response and flight characteristics. The frequencies of main concern were 3.4 Hz and its multiples. These are the frequencies of the main rotor, the tail rotor, and possible combinations. The complete testing procedures and results are contained in Ref. 2. The maximum movement measured at the magnetometer mounting ring in the boom throughout the whole flight envelope of the CHSS-2 helicopter was $\pm\frac{1}{4}$ in.

The only apparent problem was discovered when the actual AN/ASQ-8 magnetometer was installed. The standard shock mounting amplified the boom vibrations excessively, and had to be replaced by solid phenolic blocks. Although this did reduce the amplification, it was felt that the orienting gears of the magnetometer would suffer.

Equipment Installation

This phase of the program was subcontracted to C.A.E. Industries Ltd. (CAE). The oriented AN/ASQ-8 magnetometer system was selected for the trial because of its availability and cost. For compensation, the semiautomatic CAE 9 term compensator was installed because of its ease of operation and satisfactory performance to better than the 0.1 gamma level of the magnetometer. The terms originally selected for the compensator (9TC) would permit a calculation of all the magnetic fields of the helicopter. A variable low pass filter was installed to help the AN/ASQ-8 cope with geological noise at low helicopter speeds, and an instrumentation package to aid with postflight analysis.

Preliminary Flight Trials

After checking the installation in flight, a series of compensation flights was undertaken. The procedures used for compensation have been developed by NAE and CAE for fixed-wing aircraft with the 9TC. During this period, the figure of merit (FOM) for the compensated helicopter lay between 5 and 6 gamma. The FOM consists of summing the maneuver related noise (peak to peak) caused by uncompensated aircraft fields during 5° pitches and yaws and 10° rolls on the four cardinal headings. Although this FOM was very high, most of it was accounted for by helicopter fields that the 9TC did not contain, and thus could not compensate. It was also observed at this point that the filters in the AN/ASQ-8 were not sufficiently attenuating a 3.4-Hz interference signal suspected to be coming from the main rotor head of the helicopter.

Thus, before any further progress could be made, the 9TC would have to be modified to contain all the necessary compensating fields required by the helicopter, and an additional filter added to filter the 3.4-Hz interference further.

Flights with the CAE 16 Term Compensator

A filter was built to attenuate further the 3.4-Hz interference, and the compensator modified to a full 16-term compensator (16TC). The theoretical limit for the number of terms that any aircraft can have is 16. Within three flights, the FOM is reduced to 2.5 gammas. At this time it became necessary to replace the 16-term computation procedure with a trim procedure. With the revised procedure, it should have been possible to decrease further the FOM to about 1.5 gammas. A FOM of this order would represent almost pure AN/ASQ-8 system noise. Once this level is reached, further work will be limited by the sensitivity of the present magnetometer.

Future Plans

The feasibility of an optically pumped magnetometer system for the helicopter is being investigated. With such a system, which has a sensitivity of 0.01 gamma, it will be possible to explore fully the potential of the CHSS-2 helicopter as a MAD platform.

References

[1] "CHSS-2 MAD—Feasibility of an Inboard Installation by Measurement of Aircraft Magnetic Fields," VX-10 Final Rept., Feb. 17, 1965, Experimental Squadron 10, Shearwater, Nova Scotia.

[2] Rept. H1037, Nov. 1, 1966, United Aircraft of Canada Ltd.

False Signal Rejection in Optical-Infrared Collision Warning Systems

JOHN A. DECKER JR.* AND MELVYN G. MORRIS†
Comstock and Wescott Inc., Cambridge, Mass.

AND

MARTIN O. HARWIT‡
Cornell University, Ithaca, N.Y.

Introduction

THE problem of mid-air aircraft collisions is becoming increasingly severe as the air traffic density grows, and is rapidly approaching a critical point in the airspace near major terminals.[1] Many collision-avoidance systems have been proposed in the past, ranging from sophisticated onboard automatic sensors directly coupled to the aircraft's autopilot, to an extension of positive control by radar-aided ground controllers to cover all aircraft movements. In general, the ground-based systems, although clearly the best long-term solution, would require major modifications to existing facilities, the attainment of which is years in the future, at best. In the meantime, there exists an immediate requirement for a simple, inexpensive collision-avoidance system, particularly for use by general aviation aircraft. This immediate, specific need has been recognized by both NASA and the FAA, and has led to a recent NASA request for proposals[2] designed to implement such a collision-avoidance system.

In this system, every aircraft is to be equipped with a Xenon-discharge beacon lamp that emits approximately one flash per second. This flash would produce both visible light and infrared radiation in the wavelength band from 0.8 to 1.0 μ. Every aircraft would also be equipped with a set of infrared detectors whose detection response would be optimized for this wavelength band; commercially available silicon semiconductor photodetectors will suffice. (This wavelength band, specifically the 0.9 μ region, provides the fortunate coincidence of an intense line-spectrum radiation emission from the Xenon lamp, the maximum sensitivity of silicon photodetectors, and a maximum transmission "window" of both dry and wet atmospheres.[3])

Infrared radiation emitted from the Xenon light on a "target" aircraft is thus transmitted through any atmospheric haze, etc., that may be present and is sensed by the photodetectors on the "protected" aircraft at ranges substantially greater than the normal visual range for the same atmospheric conditions. The signal from the infrared detectors is analyzed electronically and used to activate an audible-warning horn. In addition, the approximate location and range (determined by signal-strength techniques) of the target aircraft is displayed on a panel-mounted collision warning indicator. This alerts the pilot to the possibility of a collision and helps him visually to locate the intruder; any evasive action taken will normally be based on the pilot's final visual sighting of the target aircraft. The function of the collision-avoidance system is to alert the pilot to possible danger and to tell him approximately where to look for the source of this danger.

Problems

There are two major problems involved in setting up such a collision warning system.

1) The rejection of all signals other than those from aircraft Xenon-discharge lights involves the rejection or discrimination against direct or scattered sunlight, moonlight, artificial illumination from city lights, and atmospheric OH emission lines in the spectral region beyond about 8000Å.

2) The problem of self-illumination, namely that the light source on the protected plane is so strong that stray light from its own lamp reflected off parts of the plane, or even off nearby wisps of clouds, could produce false signals. These signals can be eliminated by discriminating against any signals received during the time when the aircraft's own Xenon flash tube is on. However, that would mean that roughly one target plane in 500 would emit a flash that would overlap in time with the flash from the protected plane and would therefore not be detected; one cannot afford to have this high a probability of a target plane remaining undetected.

Solutions

1) Perhaps the best way of attaining the necessary degree of false signal discrimination is through an electronic scheme which effectively measures the light pulse duration. All the natural "false" light sources mentioned previously vary slowly with time; the sun, for instance, may disappear behind clouds, but the time scale involved is quite slow compared to the millisecond-duration flash of a Xenon discharge. Artificial lights, on the other hand, can be turned on quite rapidly. Once turned on, however, these lights tend to remain lit for some time. This means that a circuit requiring both a fast turn-on and a subsequent turn-off, 1 msec later, can be used to discriminate against most natural and artificial lights. From time to time a false signal will, of course, be registered; one might think, for instance, of sunlight reflected off a distant moving automobile windshield. Such events, however, are rare and will simply contribute to the over-all system noise. This is not too serious, because the presence of a target plane will generally be characterized by a series of signals spaced at approximately 1-sec intervals, while the noise sources would usually lack this repetition rate.

2) We have already mentioned that one can eliminate difficulties arising from self illumination by discriminating against signals received during the flash of the protected plane's own lamp. There are a number of ways of doing this electronically, the simplest being merely to turn off the detector for the duration of the flash; more sophisticated

Received September 17, 1968.

* Director, Physics Group, Space Physics Division. Member AIAA.

† Director of Electrical Engineering, Space Physics Division.

‡ Professor of Astronomy, Center for Radiophysics and Space Research.