SEVENTH EUROPEAN ROTORCRAFT AND POWERED LIFT AIRCRAFT FORUM

Paper No. 61

AN AUTOMATIC MAP READER SUITABLE FOR USE IN HELICOPTERS

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September 8–11, 1981

Garmisch-Partenkirchen
Federal Republic of Germany

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Abstract

This paper examines some of the problems related to tactical helicopter navigation, and describes an independent equipment development in this field by Marconi Avionics.

The shortcomings of current visual and dead reckoning navigation techniques are addressed in the context of NOE helicopter flight. The capacity of equipment such as the Doppler Navigation System is reviewed, and one extension of this enhanced navigation capability, the use of a map display, is described. The various techniques which are available for a map display are reviewed in the context of suitability to the helicopter application.

The Automatic Map Reader developed by Marconi Avionics, and specific benefits which this approach provides, are discussed. The results of flight evaluation of this equipment are also presented.

1. Introduction

The requirement for precise navigation has become an increasingly important feature of helicopter operation, as the scope of operational modes of the helicopter has increased. This is particularly true in the case of tactical operations of the military helicopter, and the search for equipment which releases the crew from the task of navigating has intensified as a result. In the field of fixed wing aircraft, navigation by visual reference and dead reckoning has been gradually superseded by an increasing sophistication of equipment, and this development has led to equipment, such as Doppler Navigation systems, being applied successfully to rotary wing aircraft. The additional developments of Map Displays have only recently been identified as potential aids to the helicopter crew. These display systems serve to provide an automated transfer of position information from the navigation source into a position related to surrounding terrain. In the majority of helicopters, this final navigation task must be performed by a crew member. In order to determine the real needs of the helicopter navigator, it is essential that the problems involved are understood. Only then can realistic solutions be proposed, with the additional constraints improved by cockpit space available and extra weight penalties taken into account.

It must be appreciated however, that different modes of flight will require different solutions as a result of the associated problems. One such flight mode which presents a particular set of problems for the helicopter navigator, is Nap-of-the-Earth (NOE) flight. It has been established that the NOE mission will be a major part of any future conflict involving the tactical operation of helicopters, and it is therefore essential that any aids which will increase the success of such missions are available today.

2. NOE Navigation Problems

In order to determine the extent of potential difficulties of NOE Navigation, the measured performance achieved using more traditional techniques may be examined. Tests conducted by the US Army in the early 1970s (Ref. 1) showed that when NOE routes were flown with Cobra helicopters, course deviations of between 500 and 2000 metres occurred, and also that aviators became disorientated en-route in 33% to 50% of test sorties.

In 1972, the US Army NAVCON (Navigation and Control Systems) issued a statement of 'Position and Navigation System Requirements' calling for a mix of externally referenced, hybrid and self contained systems to provide a position accuracy of 25 to 250 metres CEP. Further US Army testing, in 1974, suggested that using conventional techniques, the probability of navigating NOE to within 100 metres of an identified position was 0.77 (Ref. 2). The extent of the problem is therefore very serious, and must be broken down into its constituent parts in order to determine a potential solution.

Two factors unique to the NOE mission can be considered as the major reasons for navigation difficulties (Ref. 6).

Map-Terrain Correlation

In NOE flight, the helicopter crew are viewing the terrain from very low angles, and in general the major visual clues are from the horizon profile. Large areas of terrain may be obscured by landscape features or vegetation. Major reference features, such as roads and rivers are only exposed for short periods of time. The task of relating these features to an essentially plan-form representation of the standard map is therefore difficult, and disorientation can easily occur.

Head-down Time

The time available to acquire data by visual reference, and transfer this data to the map to provide navigation information, is considerably reduced in NOE flight. The requirement for crew-members to fly in a head-up manner precludes the possibility of performing this task continuously, or devoting the necessary time to re-establish position on a timely basis.

These two major problem areas are compounded by several others which will increase the difficulties of performing the navigation task:

- External threats
- Weather-visibility problems
- Mission planning
- Navigation computer errors

The overall result of these combined problems is that the navigator does not have sufficient time to transfer positional information available from navigation systems into a position on the map. The area to examine therefore is equipment which is capable of performing this task.

3. Automatic Map Display Techniques

Several techniques exist by which position may be portrayed in a directly useable form. In one definitive study (Ref. 2) these have been divided into Direct View, Projected Map, Combined Map/CRT and Electronic Pictorial Display. The study concluded that the choice for Army helicopter aviation would be between Direct View and Projected Map Display. The use of such a display would provide the navigator with the ability to look ahead in anticipation of checkpoints or for updating the navigation system, and would greatly reduce the interpolation task and potential for error. A close look at the two types of display is required to determine the optimum solution for helicopters.

3.1 Projected Map Display

The projected map display (PMD) meets the general criteria of providing a continuous display of position. In achieving this aim, however, several deficiencies exist which make it a less than ideal system for consideration for helicopters currently in service. Panel space and depth, must be provided to ensure that the device may be mounted in the most suitable position. Extensive cartographic support is required in the preparation of map cassettes. Initial cost is high, and due to the complexity, cost of ownership will also be high. Associated installation costs for modification of existing helicopters will increase the overall cost of procurement. Tests conducted on a PMD in helicopters have shown significant improvement in performance over both map alone navigation and map navigation with the Light Doppler Navigation System (LDNS,) (Ref. 3) and therefore the trade-off between mission performance and initial procurement costs must be considered carefully.

3.2 Direct-View Display

The direct-view display, which may be defined as a device which can be used in conjunction with a standard map, offers the greatest potential for a simple solution to the NOE helicopter navigation problem. The device can be designed to be portable, thus obviating the need for any extensive installation provisions. The map material is one which is familiar to all aviators, and no training is required for interpretation of the map information. Similarly, the need for special preparation of maps is minimized. The Automatic Map Reader (AMR) developed by Marconi Avionics falls into this category.

4. Automatic Map Reader Design

4.1 Design Philosophy

At the start of the AMR development programme, several criteria were set out against which design solutions could be compared. These were:

- Use of totally un-prepared standard maps.
- Ability to operate as a portable, hand held device
- Unlimited orientation of map
- Low weight
- Low cost

Having carefully considered potential solutions, a design resulted whereby two transparent circular discs were overlayed on a standard map. Figure 1 shows the overall layout of the prototype AMR. On one circular disc, a radial line is engraved, and on the second disc a spiral line is engraved. Each disc is rotated by a stepper motor drive, under control of a micro-processor, Aircraft position is indicated by the intersection of the two lines (See Figure 2). To provide a heading reference, the radial line is aligned with Grid North (in the case of UTM or Grid maps), and the intersection of the two lines set to the boundary of the display area, also shown in Figure 2. Depending on the relative orientation of Grid North the map may be inserted such that North lies in any angular position around the 360° field of map display.

In the normal operating mode, the intersection of the lines on the two discs, and thus present position, is continuously updated in accordance with data received from a navigation source.

4.2 Design Implementation

The current AMR, Figure 3 has been developed from these principles. Major effort has been placed on the reduction of weight by the use of high strength engineering plastics for the housing of the AMR, but in other areas the device remains substantially similar. The AMR system has been designed as two Line Replaceable Units (LRUs), a Display Head and an Interface Unit. The task of converting data from the Navigation Computer into a form suitable for use by the Display Head has been assigned to the Interface Unit. The power supplies convert aircraft power to the levels required by the system and are also contained in the Interface Unit, removing the associated weight and heat from the hand-held Display Head. The Head itself contains the discs, drive mechanisms, display and processor electronics and system operational controls. The control panel of the AMR contains an alpha-numeric display to provide co-ordinate data and system operational mode confirmation. Provision has been made for mounting the AMR either on a knee strap or hard mount in the cockpit, whilst retaining 360° freedom of movement of the head to allow track-up orientation in flight (Figure 4).

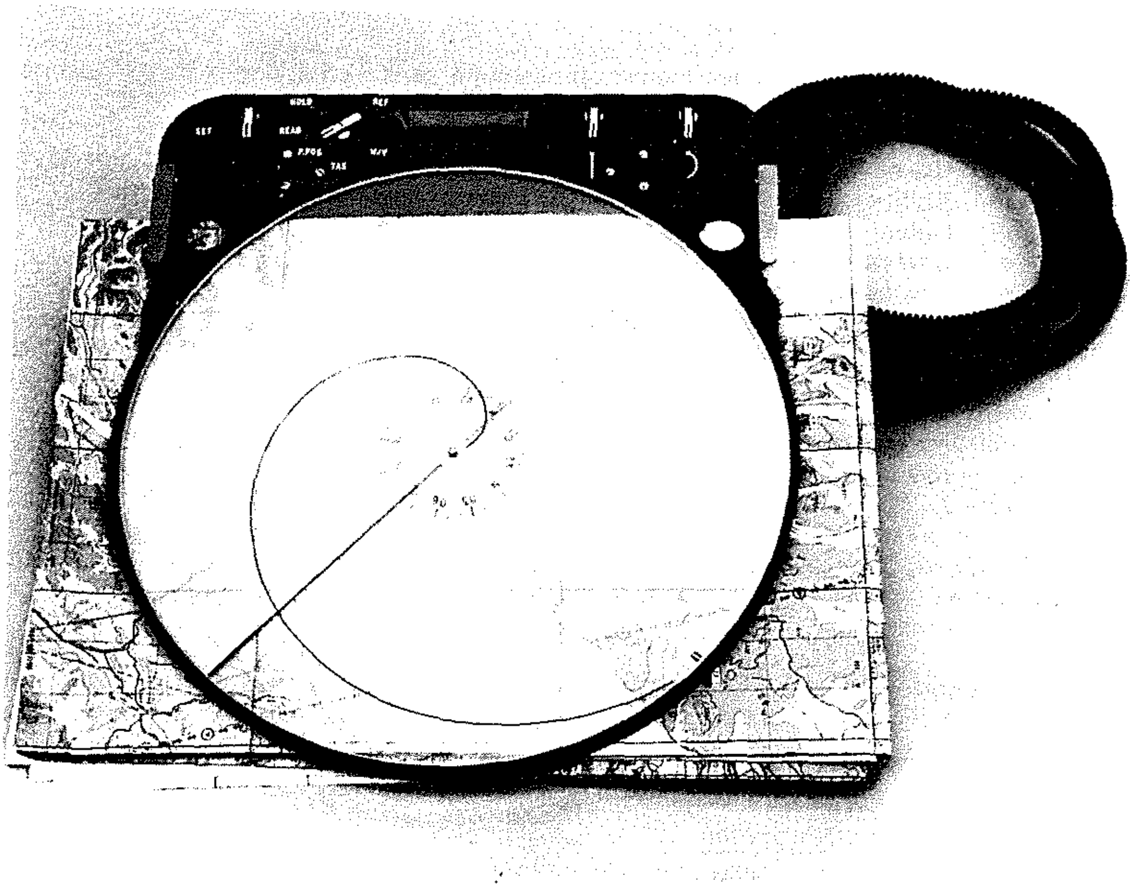

FIGURE 1 PROTOTYPE AUTOMATIC MAP READER

The present system is configured to interface directly with the AN/ASN 128 LDNS, utilizing the ARINC format auxiliary output. Alternative interfaces are possible, and studies are in progress for use with OMEGA and TANS navigation systems, in addition to future systems with a MIL-STD-1553B interface capability.

4.3 Design Benefits

The most significant benefits of the AMR relate to the use of standard maps and map orientation. The use of standard maps has been achieved in most of the developed solutions based on the direct view display philosophy. Limitations have often been imposed, however, due to, in the case of X-Y type displays, a fixed orientation of North, or in the case of circular displays, a fixed centre position. Thus in order to meet the defined criterion of unlimited map orientation, a circular display format was chosen. By transforming X-Y co-ordinates into an $R\theta$ co-ordinate system, the need to fix either the centre or North direction has been removed.

The use of un-prepared maps, folded to any thickness up to 6mm, has been accomplished by using a clam-shell case, in which the discs and drive trains are fully contained within the upper half. Thus there is no need for cutting maps and storing separate sheets in route order, or to fix devices around the map edge for positive location. As an additional benefit, therefore, the standard map is available for reversionary navigation if a failure occurs in any part of the total navigation system.

Other facilities offered by the AMR are that in addition to its use as a simple present position indicator, it may be used to automatically compute the grid co-ordinates of any other feature within the field of display by simply moving the intersection point over the desired position and reading the grid co-ordinates. Using this facility, features which may be observed during the mission, and required for later use, can be fully identified as a Grid Reference.

Similarly, pre-determined positions may be stored as way-points or targets, and may be accessed during flight to establish, for example, the desired track to over-fly the position.

5. Flight Tests of the AMR

5.1 Installations

Initial flight tests of the prototype AMR were conducted in a North American Rockwell AeroCommander 680F, to prove the principles of operation. These tests were conducted using inputs of heading, airspeed and manually entered wind vector, and thus the AMR was performing in a dead-reckoning mode. Following on from these trails, a prototype was loaned to the UK Ministry of Defence, and flown in conjunction with Doppler Navigation Systems in a Westland Sea King. The current configuration has to date been installed and tested by the US Army in a Bell JUH-IN, by Hughes Helicopters in a Hughes 500, and by the BWB in MBB B0105 and Sikorsky CH-53. All these more recent tests have been in conjunction with the AN/ASN 128 Doppler Navigation System.

5.2 Flight Evaluation Results

The tests of the initial prototype indicated that the fundamental display principles were satisfactory, and that overall size and weight were suitable for helicopter use. In the trial conducted by the Ministry of Defence, reported in Ref. 4, the display accuracy was found

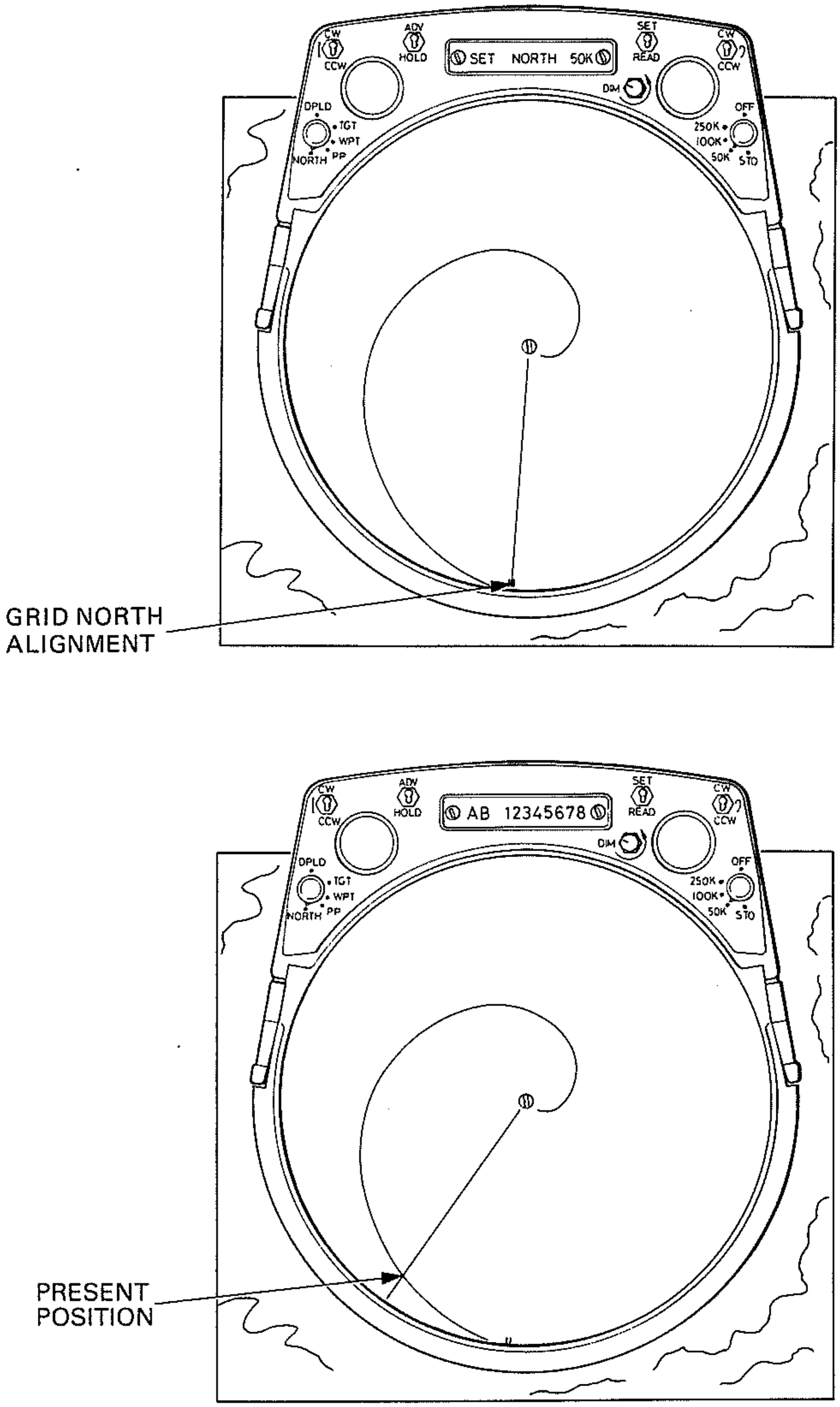

FIGURE 2 AMR DISPLAY PRINCIPLE

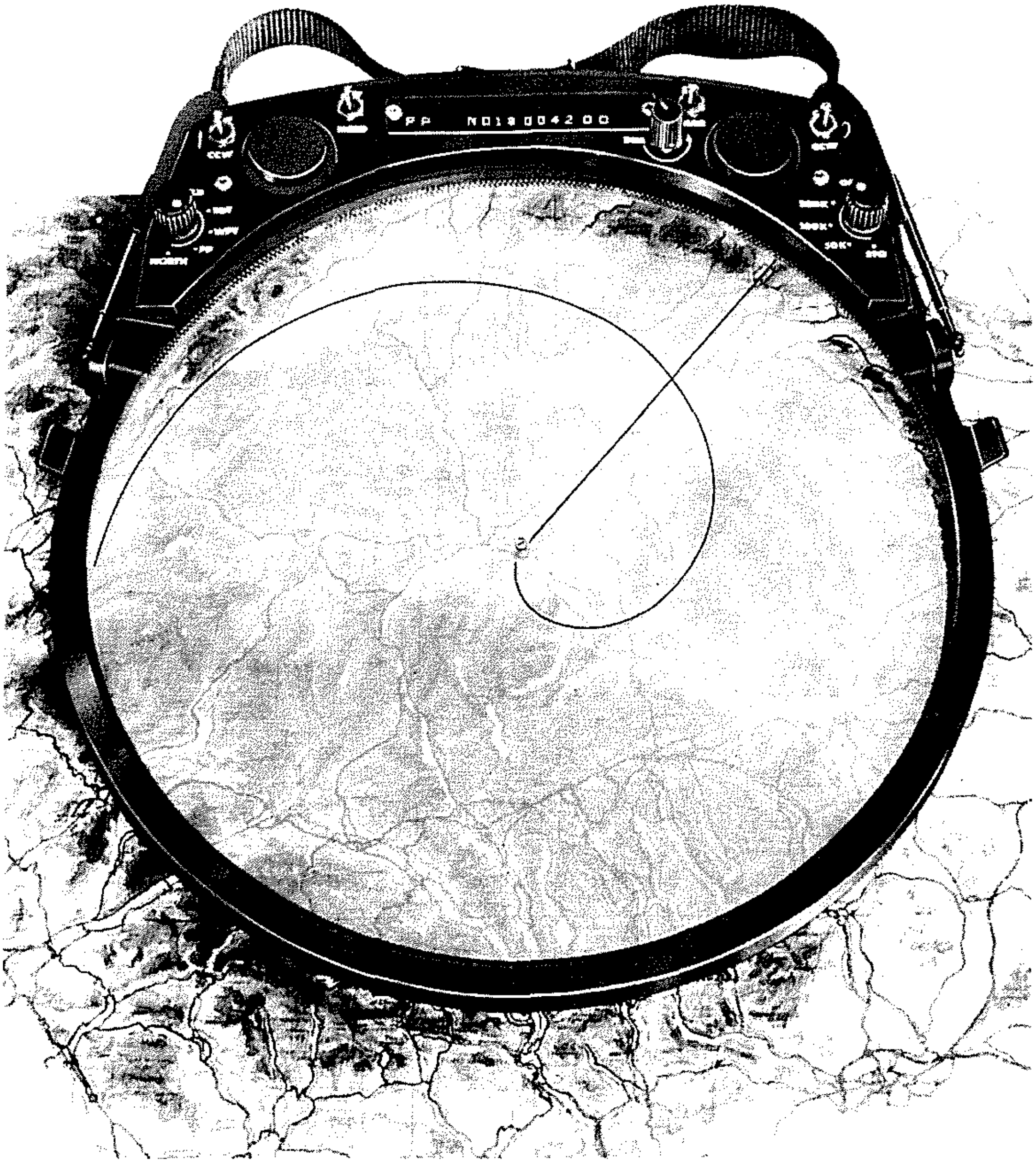

FIGURE 3 AUTOMATIC MAP READER (AMR)

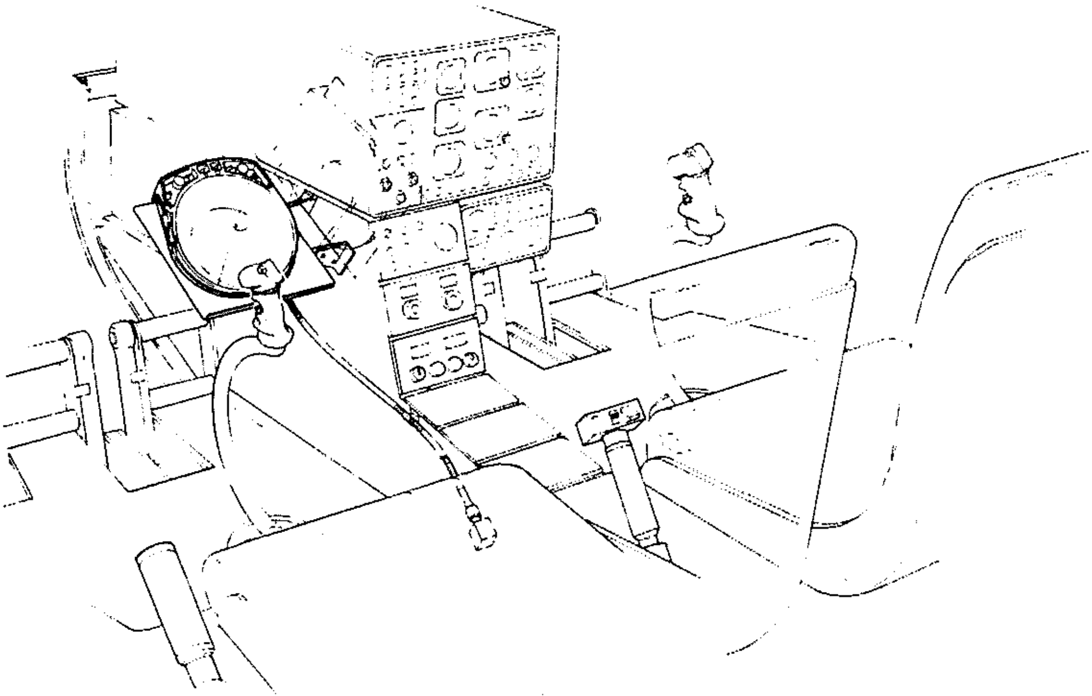

FIGURE 4 COCKPIT MOUNTING OF AMR

to be satisfactory, weight was acceptable, and controls were easy to use. Criticism was, however, made of the map retention technique. In response to this and other minor criticisms, the device was further developed to the current standard. Since the device is primarily intended as an aid to reducing crew workload, it was appropriate that the first evaluation of the new equipment was performed by the US Army Human Engineering Laboratory. Their report, (Ref. 5), concluded that "the portability of the Marconi AMR makes it an ideal candidate for installation into existing helicopters equipped with the LDNS". The AMR was also found to be a simple, inexpensive method of providing navigation data during flight in an NOE environment. Trials in Germany are as yet incomplete, and it is not therefore possible to report the results of this evaluation.

The experience gained from these trials, has indicated that there is still some scope for refinement of the design to further reduce crew workload. This is particularly true in the area of updating the display due to Doppler error, and the ability to update the Doppler directly from the Display Head. Trials have also suggested that there is a potential need for use of the equipment as a flight briefing aid. Work in these areas, in addition to the response to user comments, is in progress.

6.0 Summary

In summary, it has been established that there is a definite need for a navigation aid in helicopters, particularly in the NOE flight environment. The inclusion of a Doppler Navigation System goes some way to meeting this need, but falls short of providing a full solution. The addition of a Map Display solves the remaining problem, and to minimise procurement costs, a direct view display offers maximum advantage. The Marconi Avionics AMR, specifically developed for this application, has been proven to meet the need in terms of performance and cost, and if developed further in conjunction with Doppler Systems can become a powerful aid in minimizing crew workload before, during and on completion of the helicopter mission.

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