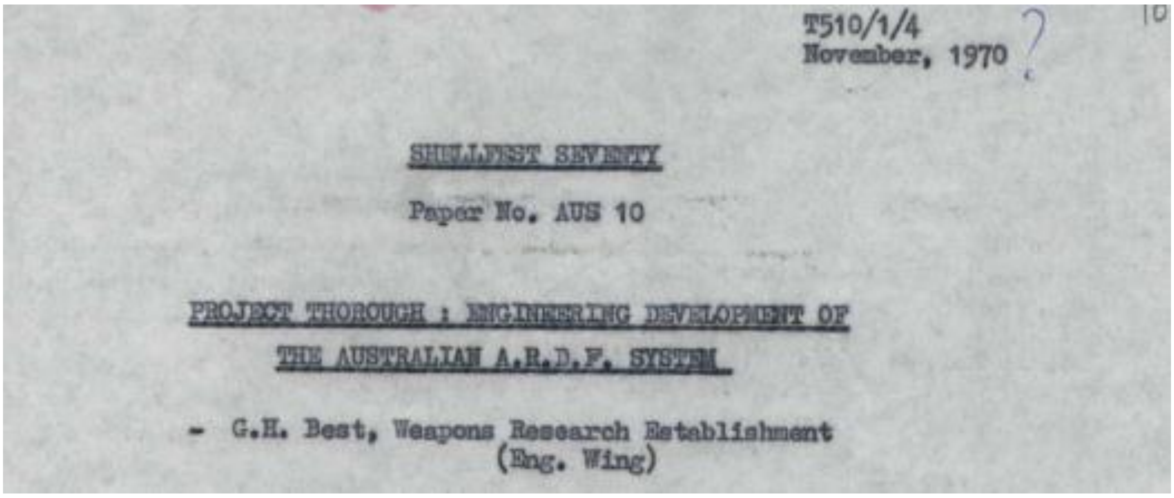
APPENDIX 3

SHELLFEST SEVENTY REPORT ON PROJECT THOROUGH

In November 1970, Gordon Best produced a paper for Shellfest Seventy[1]. The paper contained a summary of the Australian ARDF System, operating principles, equipment description, design considerations, reliability, costs, assessment of the system and future developments[2].



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SHELLFEST SEVENTY

Paper No. AUS 10

PROJECT THOROUGH : ENGINEERING DEVELOPMENT OF THE AUSTRALIAN A.R.D.F. SYSTEM

- G.H. Best, Weapons Research Establishment (Eng. Wing)

[1] Not identified.

[2] NAA: D174, E5669/3/23 Part 3. Development and manufacture of an airborne direction finding system for department of the army. F100-105.

EXTENDED SUMMARY

1. INTRODUCTION

The Australian A.R.D.F. system was developed by Ionospheric Studies Group at W.R.E., whose research has been reported at a previous CANUKAUS (Ref. 1) conference and in a W.R.E. technical memorandum (Ref. 2). Arising out of this research, two experimental models were produced (Ref. 3) and these have been in operational use for some three years. The results which have been obtained with these equipments are described elsewhere (Ref. 4).

This paper describes the development of an engineered system of A.R.D.F., based on the experimental system, which has been undertaken for the Australian Army by Communications and Electronic Engineering (C.E.E.) Division of W.R.E. The requirements stated by the Army (Ref. 5) included air safety and operational convenience features, and the extension of the frequency range of operation and environmental specifications. It was also necessary to modify certain details of the experimental version to facilitate quantity production, and to develop specifications for performance to ensure repeatability of characteristics.

The first engineered prototype has been in operation since July 1970 and two more units are near completion. Since the introduction of the first unit to the field there has been some additional work done to develop a convenient method of calibration for this equipment and this will be discussed briefly.

2. REVIEW OF OPERATING PRINCIPLES

The Australian A.R.D.F. system is operated in a light aircraft as a fly-by system operating within a distance of approximately 1 to 5 Km of the suspected target location. It is intended to provide accurate fixes from the relatively coarse position information provided by other locating systems used by the Army.

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The pilot flies along a known path, at a constant compass heading, which will pass within several kilometres of the suspected target. The D.F. operator tunes to the signal and takes a number of "cuts" along the path, recording direction and elapsed time from start for each cut. These figures are plotted on the ground, either after the flight or immediately using a secure communications link, and the position of the transmitter is estimated. Distance along the baseline is calculated from elapsed time, total time, and total distance, and direction is calculated using the dial reading, correction factor, and compass heading.

3. DESCRIPTION OF EQUIPMENT

In the interests of design economy and logistic support, standard commercial equipment has been used to the maximum extent. The system comprises a Racal receiver and a Tektronix C.R.O. together with the A.R.D.F. circuitry and mechanics developed by W.R.E. As a secondary D.F. system, a Rustrak chart recorder monitors signal strength received by a second slave-tuned Racal receiver which is fed from an omni-directional aerial. A two channel tape recorder is provided to ensure no data is lost. A block diagram of the equipment is shown in Figure 1.

Direction is determined by rotating an aerial assembly by hand until visual balance is detected on the C.R.O. screen. A scale on the operator's column gives direction referred to the aircraft axis. The aerial assembly consists of a pair of ferrite cored coils mounted in a horizontal plane at 60° to each other, together with the necessary tuning circuitry and a preamplifier. Outputs from each aerial are alternately switched to the preamplifier and receiver at a 250 Hz rate and balance is indicated when equal signals are received from both aerials. The system is sensitive to the H component of the radiated field and is vertically polarised.

This system has been shown (Ref. 3) to be superior to null direction finding systems in yielding a higher resolution for a given ambient noise level and because it is possible to monitor transmissions during the D.F. operation. Unfortunately, however, it has four positions of ambiguity compared with two for the null system, so that operating techniques had to be devised to finally determine the direction.

4. DESIGN CONSIDERATIONS

4.1 Aerial and Preamplifier

It is the aerial and preamplifier sections which have the greatest effect on performance of the overall system. Resolution is affected by the balance which can be obtained and maintained in production, and range is affected by the noise figure.

Aerial switching and the common channel preamplifier were located as close to the aerial coils as possible, and arranged symmetrically. To preserve balance, high quality diodes selected for high conductance and low capacitance were used to switch between aerials. Matching of aerial coils and the ferrite rods proved to be very important and quite difficult over a reasonably wide frequency range (1.5 MHz to 7 MHz). Ferrites were matched with respect to Q and required-tuning-capacitance using a standard coil and a Q meter. Optimisation of the Q of the input circuit was important so that the response was not too broad - reducing sensitivity and increasing the possibility of cross-modulation - or too sharp - creating tuning difficulties and increasing the problem of matching the ferrite rods.

Some difficulty was experienced specifying a figure for sensitivity which could be related simply to transmitter output and range. Standards for other types of direction finders (Ref. 6) were not wholly relevant. Because of the difficulty of coupling a noise generator to the aerial to measure overall signal-to-noise ratio, a figure for "sensitivity" was used in which the aerial was set up in the near field from a loop radiator in a screened room, and the field strength required to produce a nominal 10 db signal-to-noise ratio was measured. This method has proved to be quite repeatable. The sensitivity varies from 120 to 45 uV/metre over the band, and this gives satisfactory operation in practice.

4.2 Control Unit

The control unit houses the remainder of the electronics required to convert the commercial equipments into an A.R.D.F. system, a power converter to run all equipment from the aircraft supply, the operator's controls, and switching and interface equipment for the intercommunication system and secure communications link. The A.R.D.F. circuitry consists primarily of an elapsed time counter derived from a crystal oscillator, together with reset and display latching circuitry, the aerial switching circuitry, and various synchronising circuits. A suppressed zero metering circuit is also provided to render the AGC voltage of the second receiver suitable for indicating field strength on the chart recorder.

4.3 Mechanical Design

The mechanical design requirement was to produce an installation with the properties of light weight, reliability, ease of installation and alignment, and which met the air safety requirements of the R.A.A.F.

The equipment which evolved consists of an aluminium base-plate which mounts the rack of equipment and the operator's column. The base-plate clamps to the aircraft seat rails over the supply dropping hatch of the Pilatus Porter aircraft. The column and the radome housing the aerial system may be retracted into the aircraft for take-off and landing, and with the equipment retracted there is no external evidence of the function of the aircraft. The weight of the equipment is approximately 275 lb.

The most difficult area of the mechanical design was the selection of a mechanism to permit rotation and retraction of the radome without exposed wiring. The length of cable between the radome and the receiver had to be kept to a minimum to avoid signal loss and cross-talk from the high level switching signals on adjacent leads. Slip rings were considered unsuitable and the solution adopted uses a plug and socket which is automatically disconnected on retraction, and a small rotating loom inside the upper column housing.

4.4 Reliability

Reliability of the system is expected to be governed by the reliability of the commercial equipment. The W.R.E. designed units are of simple design and designed for high reliability. Burn-in tests have been applied to reduce premature failures.

As well as designing for reliability, rapid fault rectification has been provided for by ease of removal of equipment, use of plug-in circuit cards, provision of test cables, and the preparation of a documented test schedule.

4.5 Costs

The capital cost of the system is about $80,000 per unit, including commercial equipment, and including research and development costs spread over the three units.

Operating costs are those associated with the operation of the aircraft, pilot, and operator, together with any necessary ground support staff.

5. ASSESSMENT OF SYSTEM

The accuracy of a simple system such as this depends primarily upon the ability of the pilot to maintain a straight flight path. No navigational aids are coupled to the system so the pilot must estimate the start and finish points of each run by eye, and must hold the aircraft on a straight and level course.

Basic resolution of the system is of the order of one degree; however the accuracy of results is affected by the ability of the operator to balance the equipment on low level modulated signals, and the accuracy of the calibration curve for the equipment. Calibration is necessary to correct the field distortion produced by the aircraft structure, and this is carried out at present by flying a large number of runs around a known transmitter and plotting a correction curve from the results.

Overall accuracy seems to depend also upon topography, propagation conditions, and the type of transmitting aerial used. These are thought to affect accuracy by introducing polarisation errors. However, work is being done to investigate the area more fully.

Both accuracy and range are related to the transmitted power, the nature of the transmission, and the number of cuts which can be obtained. With the present temporary calibration curve, results accurate to within about 1 kilometre are obtained. However, with an improved calibration curve this radius would probably be reduced to about 250 metres. A meter display is being developed to supplement the C.R.O. and this will permit greater balancing accuracy. This will improve the consistency of results and the development of an accurate calibration curve.

6. FURTHER DEVELOPMENTS

A twin system is at present being designed. This will provide an airborne search position and back-up facilities in case of equipment failure in flight. This system will almost fully utilise the space and weight capabilities of the Porter aircraft.

Further developments under consideration which offer potential improvements in accuracy and efficiency include the use of a readout from the aircraft compass, and the design of a semi-automatic model. Semi-automated operation, in which all data would be recorded or transmitted to ground at the push of a button after manual balancing, is a possibility. Provision for automatic tracking after initial balancing could be provided. Computer-stored calibration data is a possibility, although a large amount of storage is required.

7. CONCLUSION

The present A.R.D.F. system has been produced to meet an urgent requirement of the Australian Army. Design was constrained by several factors, and a number of factors have not yet been fully investigated. It is, however, capable of producing useful results. Further developments such as those listed will be necessary before any substantial increase in accuracy is obtained.

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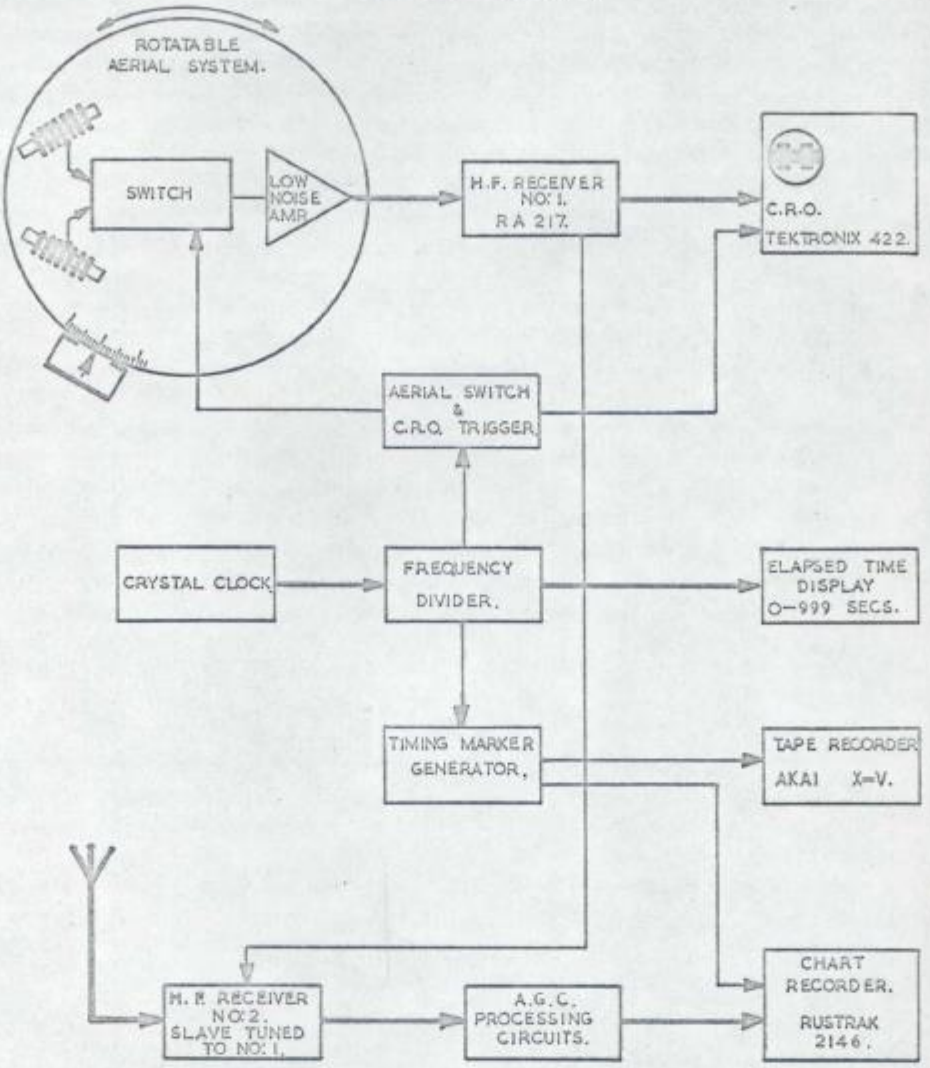

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FIGURE: I. AUSTRALIAN A.R.D.F. SYSTEM: BLOCK DIAGRAM.