SEA HARRIER FRS MK. 2 MID-LIFE UPDATE PROJECT

BY

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ABSTRACT

The Sea Harrier update to FRS 2 includes the advanced multi-mode Blue Vixen radar with automatic target prioritization. A dual redundant DEF STAN 00–18 digital databus is used for time division multiplexing, in conjunction with Panavia digital data links.

Introduction

1990 will be very significant for this very high priority project as it is towards the end of the year that the first Sea Harrier FRS Mk. 1s will enter a return-to-works programme (RTW) at British Aerospace (BAe) for modernization from which it will emerge, like a butterfly from the chrysalis, as the Sea Harrier FRS Mk. 2 equiped with a new suite of avionics, a brand new radar and ready to receive the new advanced medium range air to air missile (AMRAAM). FRS denotes Fighter Reconnaissance and Strike.

This up-date[1] will provide the aircraft with all-weather and all-aspect multiple target engagement capability by the incorporation of the AIM-120A (AMRAAM) with a new pulse doppler radar of sufficient performance and versatility to exploit the AMRAAM capability fully. The radar, designated the Blue Vixen and developed by Ferranti Ltd from a private venture radar the Blue Falcon, is integrated within a DEF STAN 00–18[2] databus controlled weapon system centred around a Bus Control Interface Unit (BCIU).

It is not possible to touch on all the various aspects of the project, interesting as they are, but the main areas of interest inevitably centre on the Blue Vixen radar and the avionics suite.

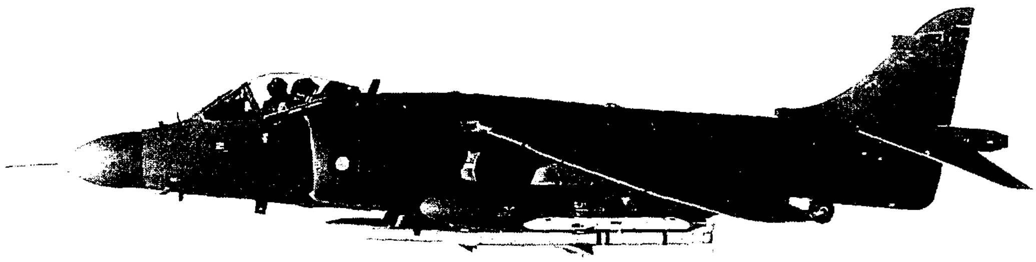

FIG. 1—DEVELOPMENT (DB) SEA HARRIER FRS 2 WITH DUMMY AMRAAM FIT

Baseline Configuration of the FRS Mk. 2

The key features of the aircraft and weapon system are:

(*a*) Four AMRAAM missiles carried as follows:
- (*i*) One AMRAAM at each outboard pylon and rail launched.
- (*ii*) One AMRAAM at each fuselage gun pod station, eject launched using LAU 106 launchers from dedicated pylons.

(*b*) Two 190 gallon tanks carried at each inboard pylon.

(*c*) 13.75 inch fuselage plug insert at frame 33.

(*d*) 8 inch extension at each wing tip (role fit only, required when carrying AMRAAM or twin sidewinders on outboard stations).

(*e*) Twin pitot static probes mounted on each side of the nose fuselage, replacing the single, nose-mounted probe.

(*f*) New rounded nose radome.

(*g*) New cooling air system for nose and rear equipment bays.

(*h*) New liquid cooling system for the radar.

(*i*) Twin head down cockpit displays—multi-function display (MFD) and radar display unit (RDU).

(*j*) Hands-on-Throttle-and-Stick (HOTAS) and Up Front Control Panel (UFCP).

(*k*) Weapon system interfacing using a combination of a dual redundant DEF STAN 00-18 digital databus and Panavia digital data links under the control of a stand alone Bus Control and Interface Unit (BCIU).

(*l*) Multi-mode forward-looking long-range pulse doppler radar system (Blue Vixen) incorporating multiple target Track-While-Scan (TWS) and Target Prioritization.

(*m*) Autopilot system to reduce pilot workload (developed for FRS Mk. 1 but to be incorporated at conversion).

Development

An integral and vital part of the project is the development programme involving the utilization of 5 aircraft—a BAC 1-11, two HS 125s and two development batch (DB) Sea Harriers. The BAC 1-11 carried out early radar performance trials using an X model Blue Vixen Radar comprising a prototype antenna, transmitter and receiver. Digitized raw radar returns were recorded and used to develop the signal processing algorithms. One HS 125 operated by RAE Bedford and fitted with an 'A' model radar commenced trials in mid 1988 to further develop and validate the radar system software. The other HS 125 (FIG. 2) fitted with a 'B' model radar and operated at BAe Dunsfold is being used to further validate the software standards being produced to support the Sea Harrier/Blue Vixen integration trials.

The two fully instrumented Sea Harrier DB aircraft (FIGS. 1 and 3) are currently utilized in the integration trials which cover aspects of development including handling performance with the new weapon configuration, EMC, and Weapon System performance which will eventually include weapon live firings.

A further Sea Harrier, designated P1, forms part of the development programme and this is the first production standard aircraft which will be used as the Final Conference (555) demonstrations aircraft. Currently this aircraft is near completion of initial general services fit, and will join the final trials programme in early 1991.

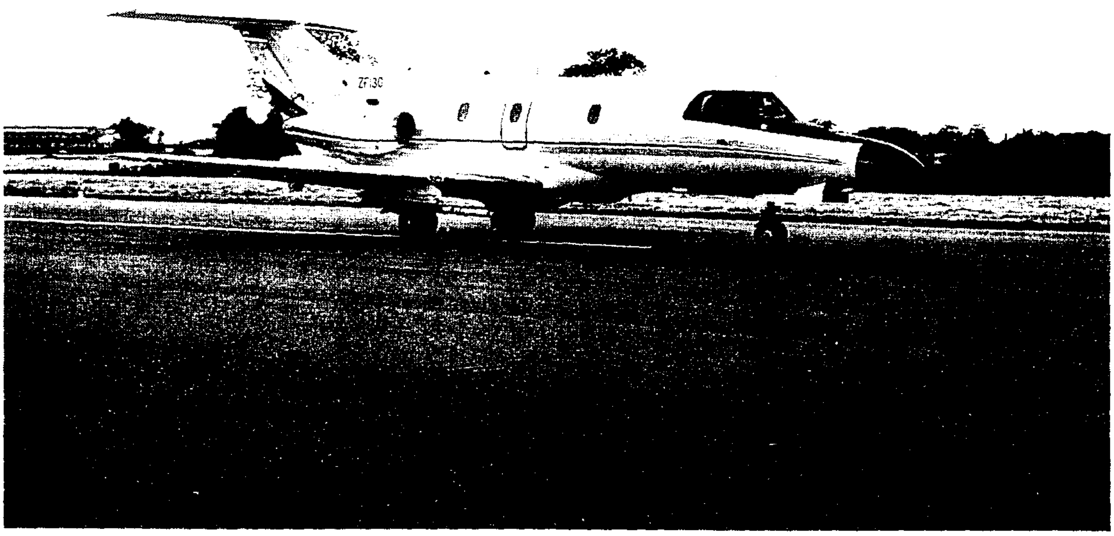

FIG. 2—HS 125 USED TO VALIDATE THE RADAR SYSTEM SOFTWARE FOR THE FRS 2

DEF STAN 00-18 Databus

DEF STAN 00-18 formerly existed as the U.S. MIL-STD-1553B and the term 1553B databus has long permeated through engineering circles. It is worth reiterating the basic principles of operation and to consider its application in the Sea Harrier FRS 2.

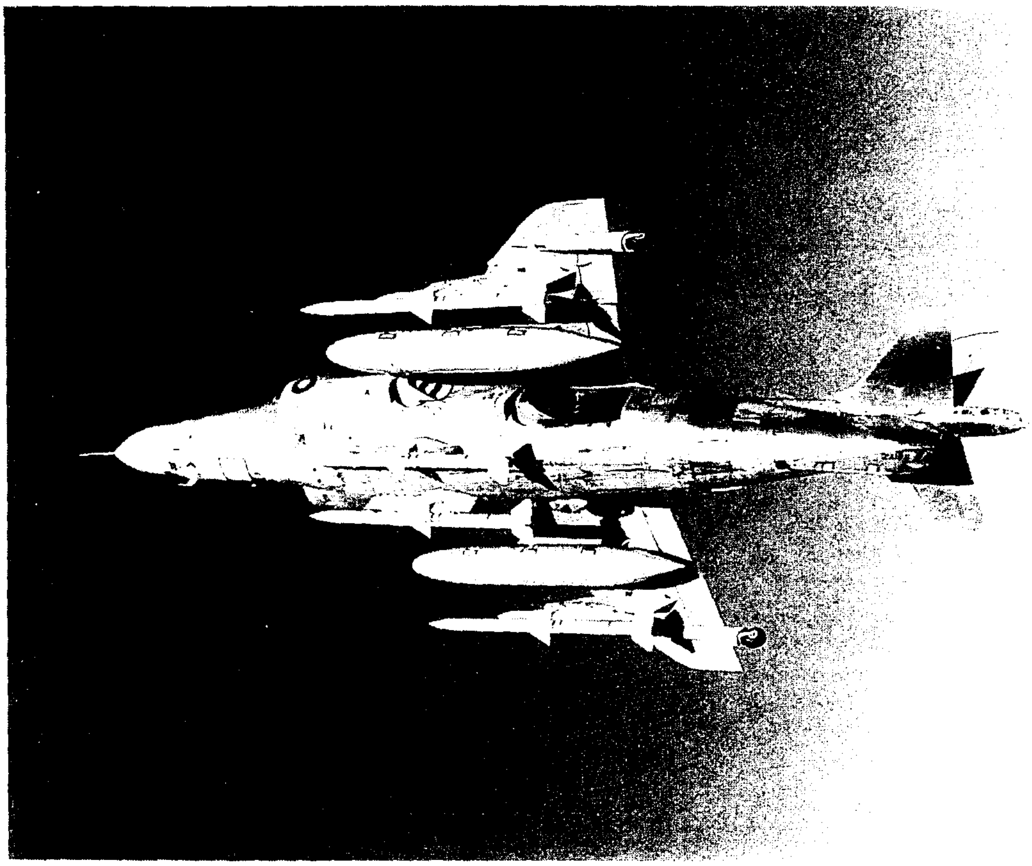

FIG. 3—DB SEA HARRIER FRS 2 WITH DUMMY AMRAAM FIT

Time Division Multiplexing

Time Division Multiplexing is the transmission of information or data between several units over a single twisted shielded pair cable, with the communications between different units taking place at different moments in time.

The Databus

The databus is essentially the hardware required to carry out time division multiplexing and includes the screened twisted pair of cables, termination resistors and coupling transformers. Terminals are connected to the databus and provide the interface between the databus and avionics units; the DEF STAN allows up to 32 terminals to be connected to the databus. One type of terminal called the bus controller (BC) is responsible for coordinating the flow of information of the databus. Other types are Remote Terminals (RT), which receive and transmit data under the direction of the Bus Controller, and Monitors which are purely passive and are used to observe the flow of information and record certain aspects of it. The Monitor terminal is normally used in a development programme only.

To achieve the most efficient flow of information a strict set of protocol rules are laid down in the DEF STAN. In simplification, the rules state that no terminals shall speak unless first spoken to the by the Bus Controller and specifically commanded to transmit.

The information flowing around the bus consists of three digital word types—Command, Status, and Data Words. Each word is 20 Bits consisting of 3 Sync Bits, 16 Information Bits and 1 Parity bit.

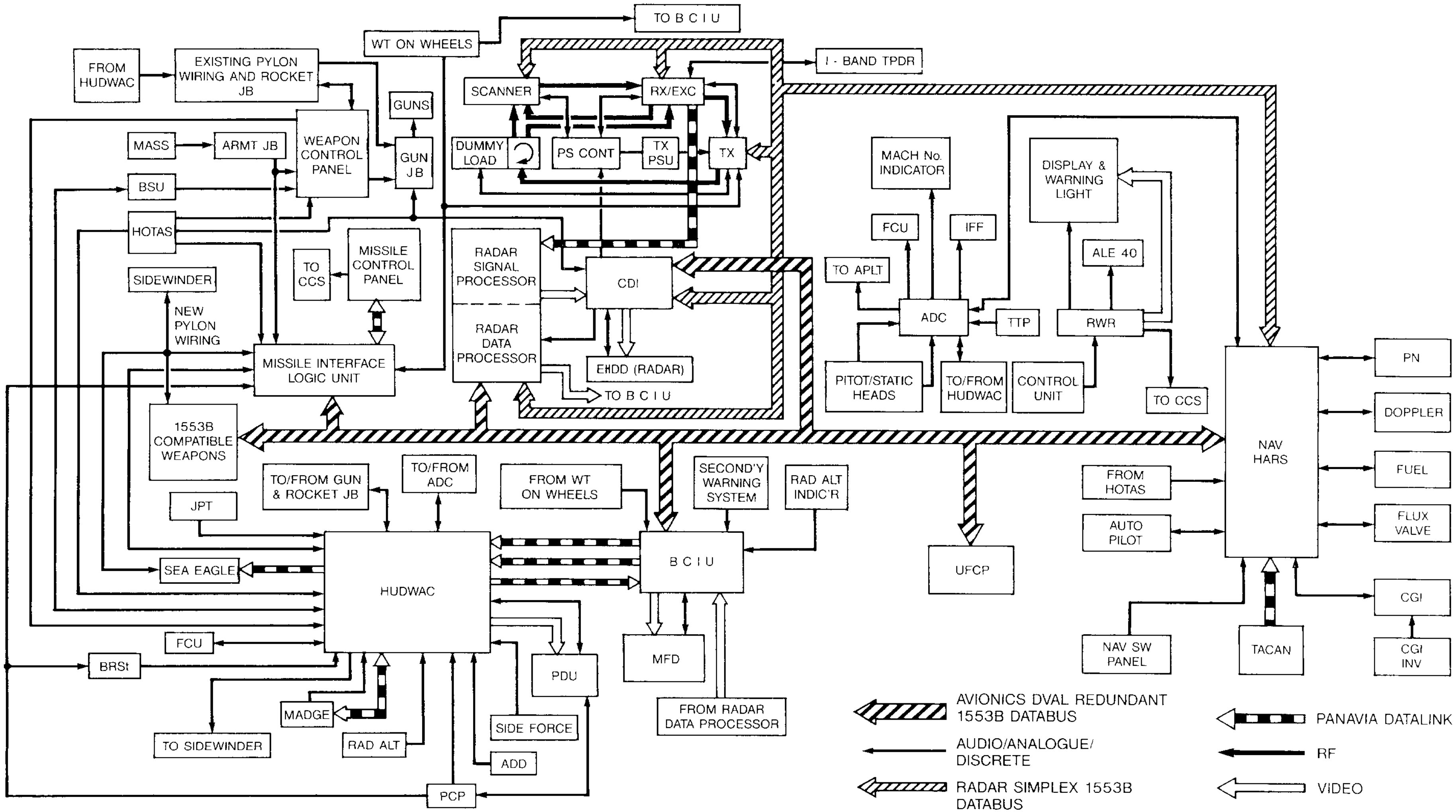

FIG. 4—SEA HARRIER FRS 2 AVIONICS SYSTEM

(*a*) *Command Word* is transmitted only by the Bus Controller and directs a Remote Terminal to either transmit or receive information across the databus. The Command Word always begins with a Sync followed by 17 information bits divided into 4 distinct fields:

Field 1—RT Address (5 bits—32 addresses)
Field 2—Sync Character (1 bit—TX or RX)
Logic One = TX
Logic Zero = RX
Field 3—Sub Address/Mode Field (5 bits)
00000 OR 11111 = Mode Control
00001 TO 11110 = RT Sub Address
Field 4—Word Count/Mode Code (5 bits)
if Field 3 = Mode Control then Field 4 = Mode Code (32 mode commands)
if Field 3 = RT Sub Address then Field 4 = Number of data words to follow

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SYNC			RT ADDRESS					T R	SUB ADDRESS/ MODE					DATA WORD COUNT/MODE					P

(*b*) *Status Word* is transmitted only by a Remote Control; it gives information on the general status of the Remote Terminal and whether any errors or corruption are detected in the information just received. The Status word always begins with Sync followed by 17 information bits divided into 10 fields:

Field 1—RT Address (bits 4, 5, 6, 7, & 8)
Field 2—Message error (bit 9)
Logic One—error present
Field 3—Instrumentation (bit 10 optional)
Logic Zero
Field 4—Service Request (bit 11 optional)
Logic Zero (if not used)
Field 5—Bits 12, 13 & 14 (for future use)
Field 6—Broadcast Command Received (bit 15)
Logic One following valid broadcast. command
Field 7—Busy Bit (bit 16)
Logic One if R/T unable to move data
Field 8—Subsystem Flag (bit 17 optional)
Logic One if R/T unable to move data
Field 9—Dynamic Bus Control Acceptable (bit 18)
Logic One if control accepted
Logic Zero (if not used)
Field 10—Terminal Flag (bit 19)
Logic One if R/T fault

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SYNC			RT ADDRESS					M E	I	S R	RESERVED			BC RXD	B	SS F	DB CA	T F	P

(*c*) *Data Word* is transmitted by either the Bus Controller or the Remote Terminals and contains the information that is to be transferred. It must be preceded by either a Command or Status Word.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SYNC			INFORMATION BITS																P

Avionics Integration

The avionics system (FIG. 4) integration is achieved using a combination of a dual redundant DEF STAN 00-18 digital databus, Panavia digital data links and analogue interfacing. The primary bus controller is the Bus Controller and Interface Logic Unit (BCIU), the radar internal databus controller being contained within the radar data processor. Partitioning of the various computing functions has been allocated to the systems interfacing with the databus, with the BCIU performing the major mission system activities of bus control and management of AMRAAM weapon aiming. Remote terminals are installed in the following units:

- Missile Interface and Logic Unit (MILU)
- Electronic Unit, Navigation (EUN)
- Up Front Control Panel (UFCP)
- Radar Data Processor (RDP)
- Control Display Interface, Radar (CDI)
- Outboard and Fuselage Pylons
- 00-18 compatible Weapons (AMRAAM)

The Radar Databus is a simplex system and contains no redundancy, the Bus Controller being part of the Radar Data Processor. Remote Terminals are fitted to the following units:

- Control Display Interface (CDI)
- Transmitter, Radar
- Receiver, Radar
- Scanner, Radar
- Electronic Unit, Navigation (EUN).

It can be seen that some units are operating on both buses and therefore contain three terminals.

All mission-related data processing is performed by the BCIU and its operational flight program (OFP). The BCIU is designed around the INTEL 8086 microprocessor and contains the following functional elements:

- 00-18 bus control hardware.
- Twin 8086-based processors each with on-board memory.
- Global memory providing inter-processor communications.
- Graphics generation providing monochrome video output to the MFD. Discrete I/O.

Software

The software resident in the BCIU is both functionally and physically split into three areas within the computer system. These areas are defined as:

- 00-18 data bus control.
- Application software, processing aircraft avionic functions and data manipulation including data processing for weapon aiming symbology for presentation on the Radar display.
- Control and processing of graphics symbology for displaying on the MFD.

All three functions are controlled by an overall software executive from one of the two main processors.

Hands on Throttle and Stick (HOTAS)

The HOTAS system provides the pilot with the capability to select weapon type, release mode, and release command from the control column handle, and the time-critical radar functions of freeze, TX on/off, marker position from the throttle handle. The HOTAS interfaces with the MILU, RADAR CDI and HUDWAC.

Blue Vixen Radar—(ARI 50019)

The new multi-mode coherent pulse doppler radar will not only provide long range target detection but also simultaneously provide each of the 4 AMRAAMs carried with accurate track and velocity information on the highest priority targets both before and after the launch of the missiles; pre-launch data being transmitted via the DEF STAN 00–18 databus and post-launch data via radar-generated data links. The system prioritizes and designates the missiles to targets automatically which will relieve the pilot of complex decision-making, thereby significantly reducing his workload during critical phases of the mission. In addition to the AMRAAM, the radar is capable of supporting all previous Sea Harrier FRS 1 roles.

Background

In comparison with Blue Vixen, previous service airborne radars were relatively simple. Some readers may remember the AWG-11 fitted to the Phantom F4, which for all its size and power only operated in one of the modes now available on Blue Vixen. The Blue Vixen radar is not more powerful, in fact the average transmitted power is probably lower than some of its predecessors, but rather it is the application of the quantum leap in technology which enables the radar to analyse the received signals to much greater depths.

Advanced antenna design, low noise receivers, high speed processors and techniques such as pulse compression and PRF scheduling are all used to extract and identify targets from unwanted returns.

Development

Blue Vixen has been developed from the Ferranti private venture (PV) Blue Falcon Radar, a project designed to provide performance data for the next generation of airborne fighter radars. Data obtained from Blue Falcon has provided the basis for not only Blue Vixen but also the ECR90 bid for the European Fighter Aircraft (EFA) and the PS-05/A for the Swedish JAS 39 (Gripen) fighter replacement for the Viggen.

Modes of Operation

Blue Vixen is a multi-mode radar which has been designed for all-weather, beyond visual range, air-to-air and air-to-surface use. It provides ten different modes of operation, a vast improvement over the FRS 1 radar, the Blue Fox, which lacks both a reliable look-down and long-range detection.

The term multi-mode refers to radars' ability rapidly to change Pulse Repetition Frequency (PRF) to extract the required information, dependent on the operational mode selected by the pilot. A variety of digital techniques are also used to overcome the problems of clutter (unwanted returns from ground or sea) and to combat the effects of various types of jamming. The ten operational modes available are listed in TABLE I.

TABLE I—*Blue Vixen operational modes*

Air-to-Air	*Air-to-Surface*
Multi-mode look-up search	Real Beam Ground Mapping
Multi-mode look-down search	Ranging
Track-While-Scan	Sea Surface Search
Air Combat Acquisition	Beacon Interrogation
Target Prioritization	
Single-Target-Track	

The Radar Data Processor performs the mode scheduling by switching the system between Low PRF (LPRF), Medium (MPRF), and High (HPRF) to obtain the highest quality of data available. TABLE II details the general performance of the radar and data quality in various modes.

It can be seen that MPRF gives the best all-round performance and will be the basis of most operations. For example, in the look-down search mode the first scan may be in HPRF to obtain good initial detection, the second, third and fourth scans may be MPRF to build up track files, and the system will then schedule the PRF to obtain the optimum results.

TABLE II—*Blue Vixen performance*

Data	*HPRF*	*MPRF*	*LPRF*
Detection range	very good	good	very good
Velocity coverage	closing targets only	all targets	all targets
Range measured	no	yes	yes
Velocity measured	yes	yes	no
Look-down perform	very good	good	poor
Look-up perform	very good	good	very good
Track-data	none	good	adequate

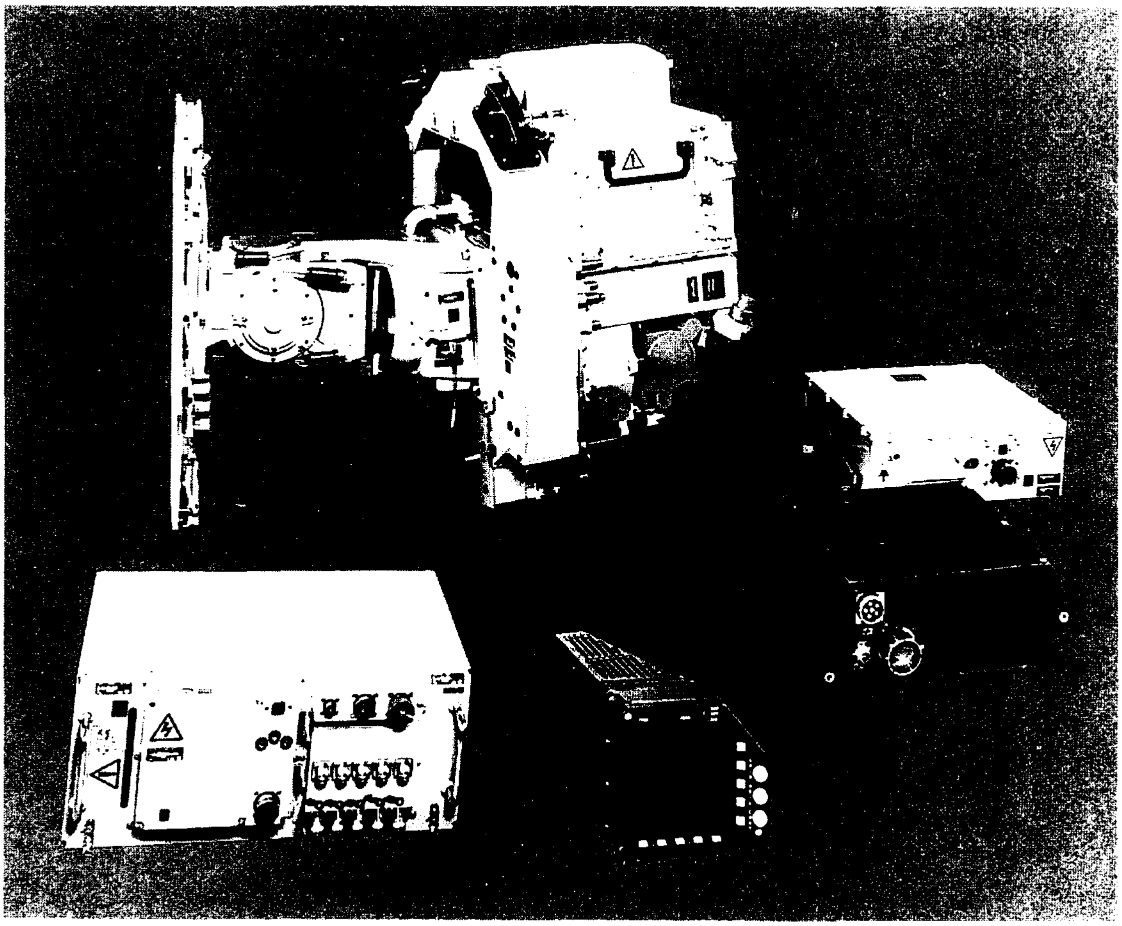

FIG. 5—BLUE VIXEN RADAR. CLOCKWISE FROM TOP LEFT:
SCANNER MAINFRAME WITH ANTENNA, TRANSMITTER AND RECEIVER/EXCITER; TRANSMITTER AUXILIARY UNIT; POWER SUPPLY UNIT; RADAR DISPLAY UNIT; SIGNAL AND DATA PROCESSOR

Hardware

The radar (FIG 5) comprises seven LRUs (Line Replaceable Units):

(*a*) Scanner mainframe (on which are mounted (*b*) and (*c*)).

(*b*) Transmitter.

(*c*) Receiver/Exciter (FIG. 6).

(*d*) Power Supply Unit (PSU).

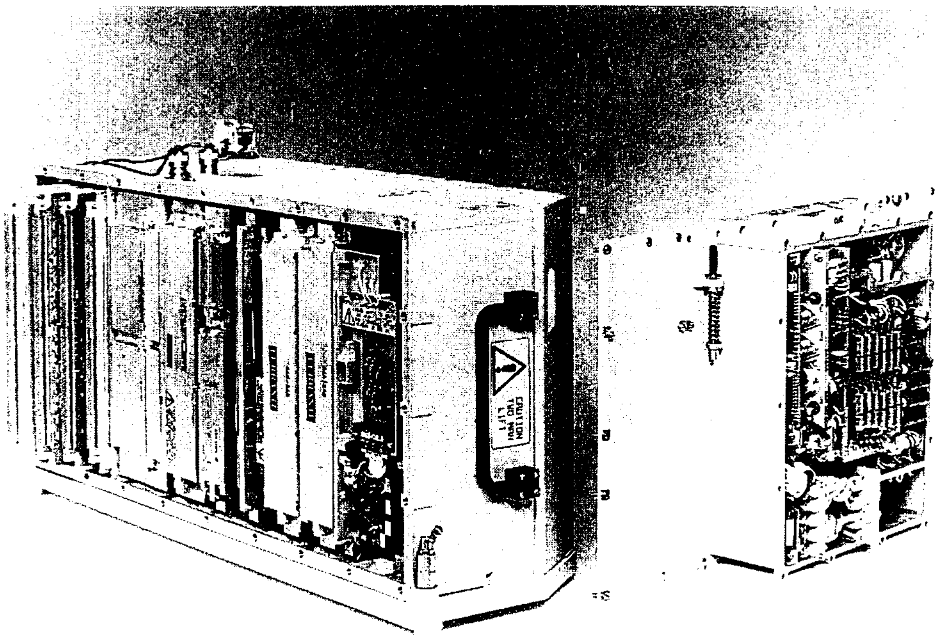

FIG. 6—RECEIVER/EXCITER

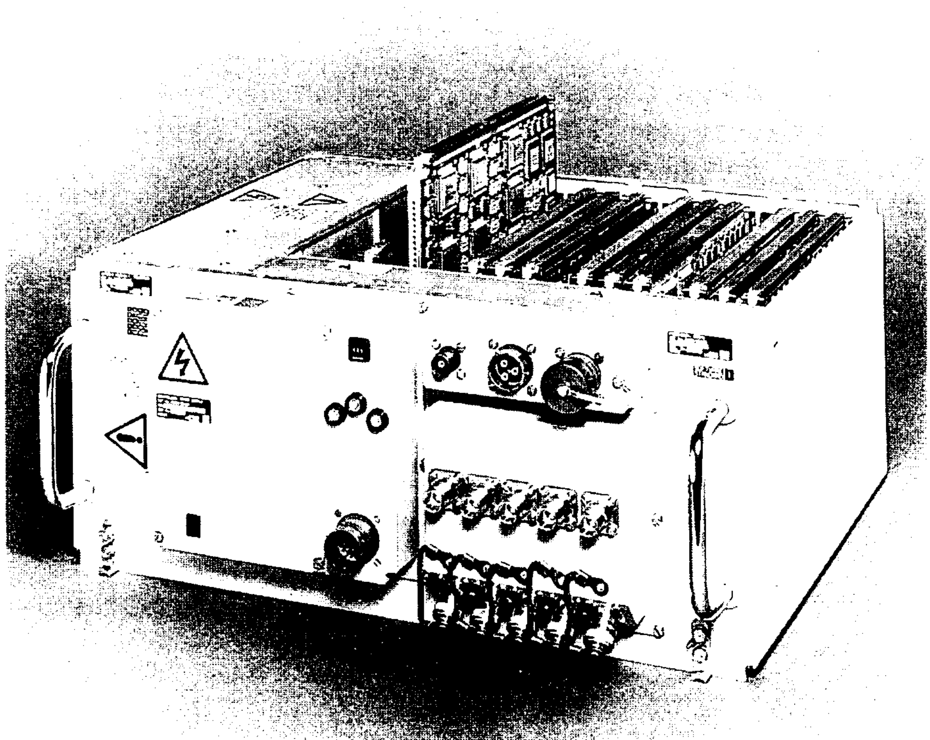

FIG. 7—SIGNAL AND DATA PROCESSOR

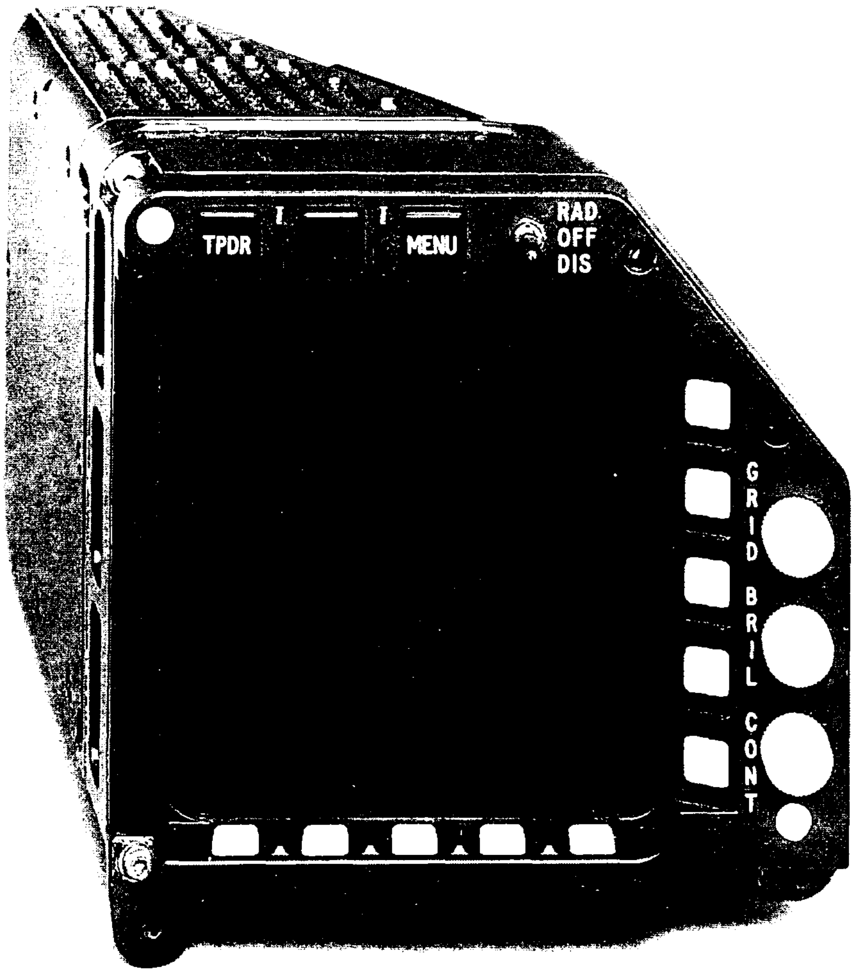

FIG. 8—RADAR DISPLAY UNIT. NOTE SOFT KEYS, AT RIGHT AND BOTTOM, FOR SYSTEM SELECTION AND SWITCHING

(*e*) Signal and Data Processor (FIG. 7).
(*f*) Control Display Interface (CDI).
(*g*) Radar Display Unit (RDU) (FIG. 8).

The location of equipment in the aircraft is shown in FIG. 9. The main difference from the Blue Fox is the location of the combined signal and data processor in the rear equipment bay. Fibre optic links are used between the receiver, the processor and the CDI to carry the high data rates of digitized IF and video signals and to prevent corruption in the EMC hostile engine bay. The main link between LRUs for the passing of instruction and data is a simplex 00–18 databus.

The Nose Bay equipment consists of a Mainframe and Antenna Platform upon which are mounted the Transmitter (together with the Transmitter Auxiliary Unit and the Transmitter Power Amplifier (FIG. 10)) and Receiver/ Exciter. A special feature of the transmitter is the liquid-cooled Travelling Wave Tube (TWT), which transmits a pulsed signal as part of a continuous waveform. This is termed 'Frequency Coherency', and enables successive target returns to be added together and analysed very accurately. The liquid coolant is an inert silicon-based fluid which not only cold-wall cools the modulator in the TX but directly cools the anode in the TWT. The high current d.c. power supplies required to drive the transmitter are generated in a separate LRU (the PSU) mounted on the hinged camera bay access door.

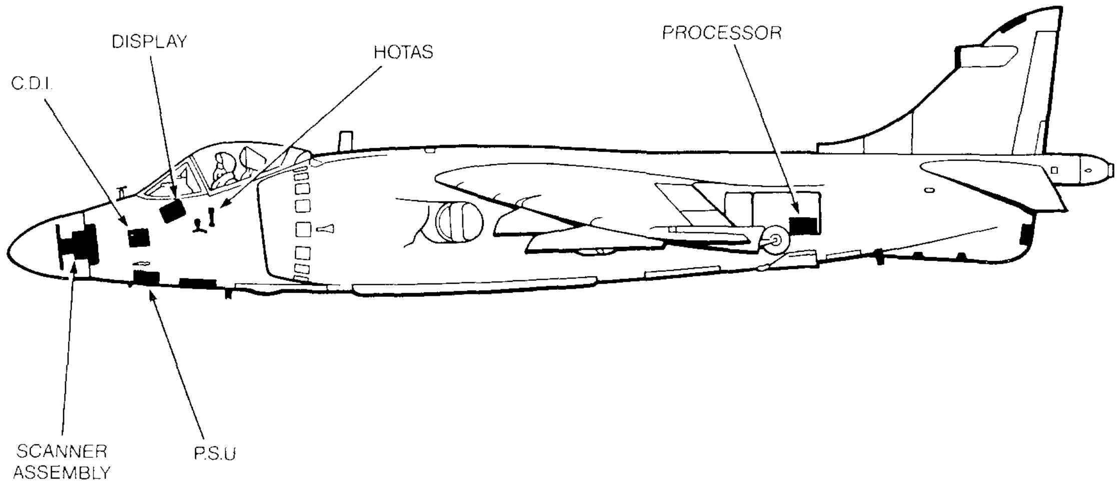

FIG. 9—LOCATION OF LRUs, ETC.

Antenna and Receiver operations are conventional although extensive use is made of microprocessor control and digital techniques. In particular the antenna is driven by high speed d.c. motors under the control of a dedicated processor, thus giving extremely accurate positional control.

Contemporary printed circuit manufacturing technology is used in the production of the Processor, i.e. high density, multi-layer, surface-mounted components, microwire circuitry and advanced cooling techniques. The cockpit units are similar in size to their Blue Fox equivalents, although LRU weight is increased. System selection and switching is by the RDU soft keys (FIG. 8) or by the HOTAS (see FIGS. 11 and 12).

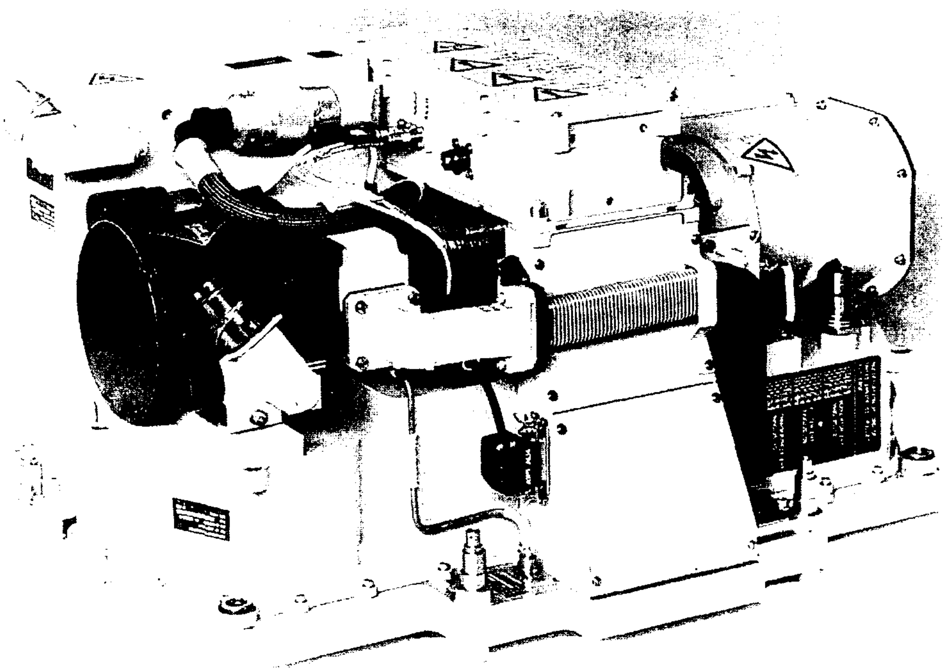

FIG. 10—TRANSMITTER POWER AMPLIFIER

Software

System capability is entirely software-dependent, providing inherent flexibility and reliability, and allowing changes to be proven readily and quickly on specially designed dynamic rigs before flight trials. However, the initial writing, proving and validation is a complex, lengthy process and is labour-intensive, although much of this is also software-mechanized.

Within the system are five different general purpose microprocessors plus a number of special purpose processors within the Data Processor sub-unit. A mixture of languages is used throughout the system, ranging from assembler in various forms to three high-order languages: Coral, Pascal and Pascal-D80. In-service support of software will be confined to the Graphics PCB in the CDI which is written in Coral.

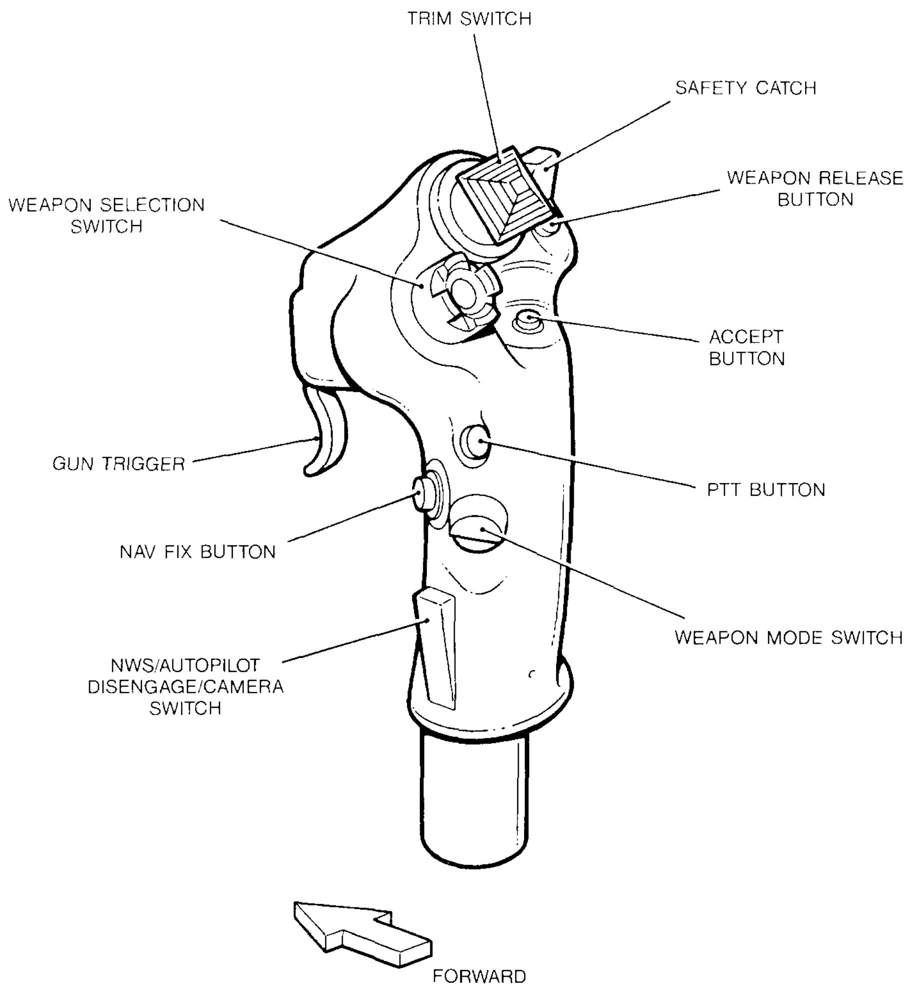

FIG. 11—CONTROL COLUMN HANDLE

Radar Architecture and Operation

The Blue Vixen comprises two main elements—a transducer and a computer—and being part of the avionic system it receives data from and passes it to the Avionic bus. The existing FRS 1 Electronic Unit (Nav) has been extensively modified to enable it to pass high rate azimuth and elevation data for the scanner pointing. Simplified control and operation of the radar are best described as a sequence of events read in conjunction with FIG. 13.

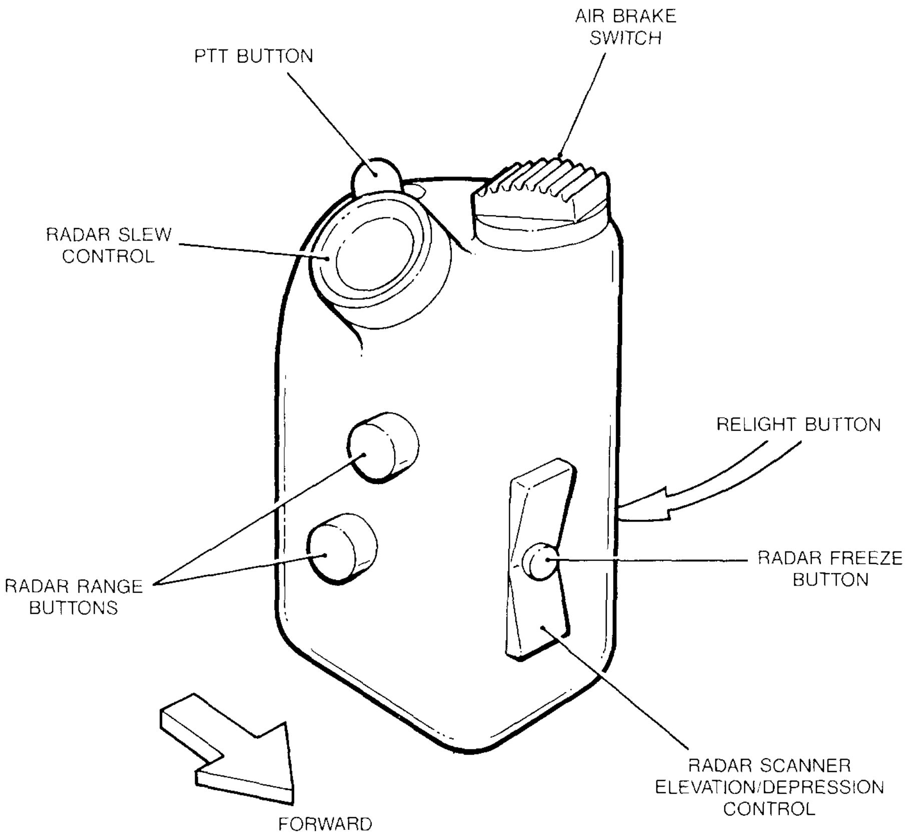

FIG. 12—THROTTLE HANDLE

Sequence of Events

(*a*) Instructions on the required radar function are received by the Data Processor from the HOTAS and Radar Display Unit (RDU) controls via the CDI.

(*b*) The Data Processor selects the mode, the precise waveform to be transmitted and the required antenna position. It configures the Signal Processor to handle these parameters, and then passes this information to the transducer via the radar bus.

(*c*) The Exciter generates the required waveform.

(*d*) The Transmitter amplifies the radar signal.

(*e*) The Antenna is driven to point in the required direction.

(*f*) All signal returns are fed to the Receiver where they are amplified, digitized and passed via fibre optic links to the Signal Processor.

(*g*) The Signal Processor extracts the target/targets from the clutter and passes them to the Data Processor.

(*h*) The Data Processor either compiles and stores track files or builds a map image for direct display via fibre optic link and the CDI. Track information is placed on the radar bus for display and on the avionic bus for use by the nav/attack and weapon system.

Servicing and Built-In Test

Micro-processors in each LRU have produced a great improvement in the quality and reliability of BIT. Tests are carried out either continuously, periodically or on the command of the operator; the latter, known as interruptive BIT is normally only carried out on the ground as it interferes

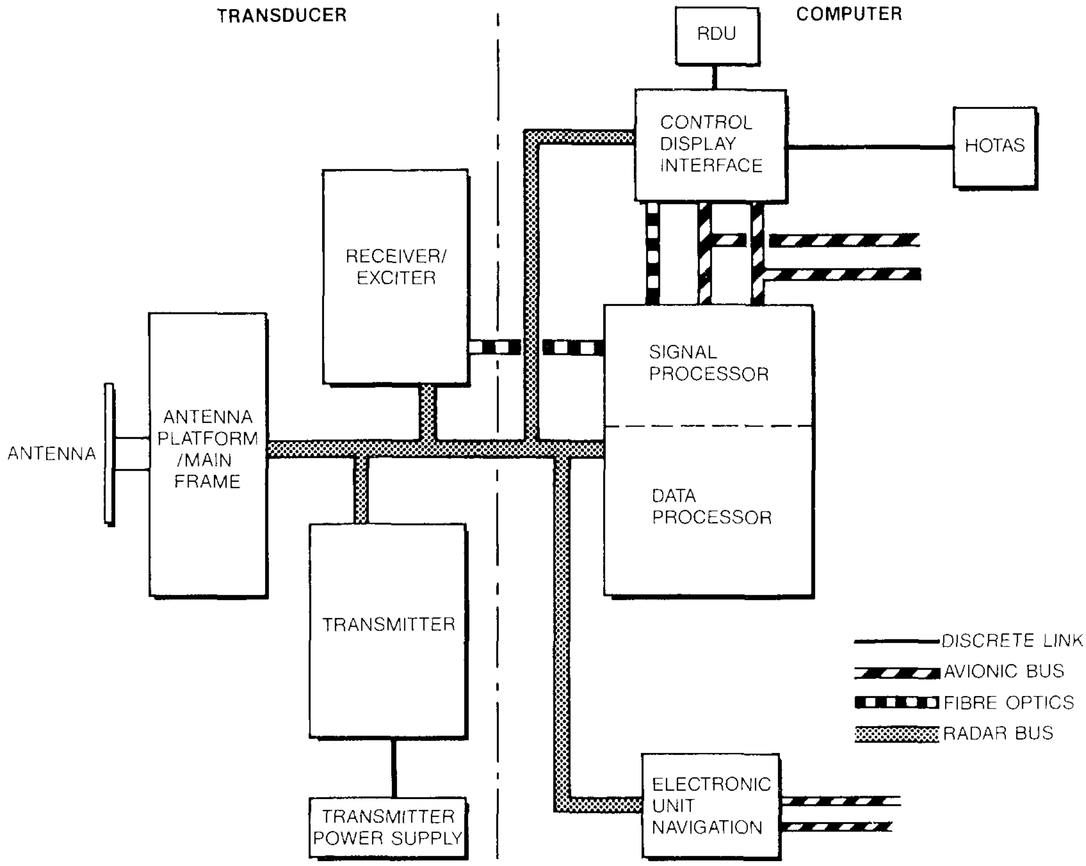

FIG. 13—BLUE VIXEN RADAR

with the normal operation of the radar. Continuous and periodic BIT are completely invisible to the operation of the radar and require no pilot/ maintainer participation.

Faults detected during BIT are classified protective or non-protective; the former will cause a partial shutdown of the system to prevent any potential damage being sustained. All faults are logged in an erasable memory area in the CDI, which can be accessed directly via the Radar Display Unit and can be downloaded to a portable storage device via the BCIU for 2nd line analysis.

Part of the BITE function is to provide an auto-calibration facility. Traditionally, manual adjustments have been made to analogue sections of a radar, but now with digital technology it is possible to inject a known signal into the receiver, and comparisons with what should be received at various stages allow automatic adjustments to be made.

Conclusion

Results of the development programme to date clearly indicate that the combination of the avionics suite, Blue Vixen radar and the AMRAAM will make the Sea Harrier FRS 2 a most versatile, effective and potent weapon platform and will be a significant addition to the Fleet's weapon inventory.

References

1. Plumtree, H. M. J. and Burlingham, M. J.: Sea Harrier a mid-life update; *Journal of Naval Engineering*, vol. 28, no. 3, Dec. 1984, pp. 478–484.
2. Defence Standard DEF STAN 00–18: 'Aircraft internal time division command/responsible multiplex data bus' (Nov. 1983).