# DEFENSIVE AVIONICS FOR FIGHTER AIRCRAFT - DESIGN CONSIDERATIONS WITH EMPHASIS ON SYSTEM INSTALLATION

S. Bimalkhedkar* and C.H. Durga Prasad**

**Abstract**

*A fighter aircraft is vulnerable to precision radar guided weapons of the adversary Air Defences. The aircraft survivability can be enhanced only by equipping it with modern Defensive Avionics. The Defensive Avionics typically comprises wide band sensitive receivers, powerful Signal Processors and high ERP transmitters. The sensitive receivers get affected by on board transmitters and the transmitters of the Defensive Avionics may interfere with satisfactory operation of other onboard avionics. Mutual compatibility is usually ensured by suitable temporal, spectral and spatial management techniques. The restricted spaces and limited ECS for cooling the Defensive gear call for careful tradeoffs to be made. The paper addresses these considerations and tradeoffs and suggests practical solutions to ensure that Defensive Avionics suite performs its role without degrading other avionics operation.*

## Introduction

Recently fought battles have demonstrated that a fighter aircraft is vulnerable during its strike missions from the adversary air defence precision radar guided weapons. Thus mission accomplishment is questionable, no matter how capable the aircraft is and lethal its armaments are. It is, therefore, essential to ensure the aircraft survivability by equipping it with Defensive Avionics which alone can render adversary air defence radars ineffective. It is well known that attaining air superiority paves the way to winning the battle and that air superiority is itself preconditioned to winning the electronic battle with Defensive Electronics. This paper addresses the design and implementation of Defensive Avionics for a fighter aircraft and considerations that govern its installation and integration.

## Threat Scenario

A fighter aircraft in its mission, such as ground attack, encounters initially long range Early Warning radars, Ground Control Interception radars and Acquisition Radars. As it approaches and crosses the geographical boundary with the adversary, it is intercepted by AI Multi Mode FCR Radars. In the terminal phase of the attack the aircraft is threatened with Surface to Air missiles guided by Fire Control Radars and Anti Aircraft Artillery guided by FCRs. Thus, the aircraft is threatened with various layers of air defences. The Early Warning Radars and GCIs and Acquisition Radars are masked with Stand-Off ECM, Stand-In ECM and Escort ECM systems carried on air vehicles supporting the strike mission. The terminal phase threats such as Air Borne AI radars, Ground based FCRs and AAA radars have to be neutralised with a Defensive Avionics Suite carried by each strike aircraft. Fig.1 [Ref.1] illustrates the effect of Defensive Avionics on the performance of Adversary Air Defence radars. It can be seen from the figure that even moderate amount of ECM activity from Defensive Avionics succeeds in forcing the air defence radars to revert from automatic to manual mode of operation and with intense ECM it has to revert to other back up modes of operation such as optical. Hence the necessity of Defensive Avionics on every fighter aircraft.

## Defensive Avionics Design and Architecture

Given the threat scenario described above, the Defensive Avionics must include a sensitive Radar Warning Receiver (RWR) to provide the pilot with a timely situation awareness detailing the active threatening radars, their Direction Of Arrival, mode of operation, lethality level and an audio alert when a new guy appears. The Defensive Avionics must also include an Electronic Attack (EA) system which is driven by the RWR and also capable of autonomous operation with own receiver. The EA system must be broad band to encompass the range of threat radar frequencies and possess matching Electronic Counter Measure Techniques repertoire to effectively tackle the specific modes of radar operation. Further, the

* Scientist ‘G’ ** Scientist ‘D’
Defence Avionics Research Establishment, New Thippasandra Post, Bangalore-560 075, India
Email : sbimalkhedkar@vsnl.com; chprasad2003@yahoo.com

EA system should have a high power microwave transmitter combined with a transmitting antenna to generate Effective Radiated Power (ERP) to neutralise the tracking and guidance functions of the threat radars. A passive Counter Measure Dispensing System (CMDS) is also required to complement the active EA system and the RWR. The operation of these subsystems of the Defensive Avionics should be controlled from a Control and Display Unit (CDU). DARE, Bangalore together with DLRL, Hyderabad and ADE Bangalore has designed and implemented such a Defensive Avionics system for the MiG 27 fighter aircraft.

The architecture of the system is given in Fig.2.The RWR provides 360 degrees angular coverage and S, C, X and Ku band frequency coverage. It is capable of intercepting all types of radars and measures their parameters such as frequency, PRI, PW, Pulse Amplitude and DOA accurately, builds Emitter Track Files, identifies the emitters with the help of a Pre Flight Message (PFM) threat library and displays the threats with alpha numeric and special graphic symbols on the Display Unit. The RWR can cue a CMDS equipment via an RS 422 serial bus.

The EA system is implemented in two segments: Segment I is the High Band (HB) system and Segment II is the Low Band (LB) system. Segment I is internally mounted and is integral with the aircraft. It is capable of countering low duty cycle ground based FCRs and also high and medium duty cycle airborne AI FCRs. Segment II is a pod mounted EA system. The EA system can operate in RWR cued mode and also in autonomous mode and is driven by a PFM. The PFM provides the requisite ECM response data against identified threats. Technique Generators in Segment I and Segment II of the EA system produce the ECM waveforms in real time and modulate the radar signals stored in the system or modulate tuneable Voltage Controlled Oscillators set to the radar signals. Comprehensive look through allows the EA system to dynamically adjust its response to the changing threat scenario. The system's ECM resources are allocated on a priority basis.

The threats responded to are indicated in the display unit with suitable attributes to the symbols. Thus the pilot gets to know the surrounding threat scenario and the way Defensive Avionics is responding to it.

Figure 3 shows the LRUs of the system. The system is installed on MiG 27 aircraft and flight evaluated and manufactured in limited quantities. It is in operational service.

### Installation and Integration

Installation and integration of LRUs on fighter aircraft and their interoperability with other onboard avionics is a challenging task. Suitable locations for Rx and Tx antennas and the LRUs of Defensive Avionics Suite were identified after a detailed study. The installation scheme arrived at is shown in Fig.4.

Some of the problems encountered and resolved during installation and integration are given below:

- There was an appreciable amount of RF energy coupling between the transmit antennas and the receiving antennas. To increase the isolation between Tx and Rx antennas appropriate polarizations such as right hand circular and left hand circular were adopted. Also for the concurrent operation of EA and RWR, the RWR issues blanking commands to the EA system during its reception. A minimum cycle time is ensured to prevent RWR from blanking the EA system excessively.

- The masking of Rx/Tx antennae due to aircraft structure and projected surfaces was assessed. This assessment was compared with measurements in the field. The Rx antennae masking due to structure was compensated in the operational software.

- The thermal management of LRUs posed a tough problem. The ECS supply of cool air was limited and had to be apportioned judiciously amongst the LRUs. The distribution of air flow is shown in Table-1. The high power LRUs were also equipped with blowers to prevent hot spots at the TWT collectors. The aft HB Tx is located in the fin root of the aircraft where it was not possible to route ECS air supply. Evaporating liquid "METHANOL" is used as coolant for this LRU. The unit has sealed coolant chamber which can store 2.5 litres of Methanol and needs periodic replenishment.

**Table-1**

| LRU \ Parameter | Heat Load (W) | Air Flow Rate (Kg/hr) |
|---|---|---|
| HB Low Duty Tx/Rx | 635 | 37.5 |
| HB High Duty Tx/Rx | 760 | 43.5 |
| HB Signal Processor | 100 | 04.0 |
| Total | 1495 | 85.0 |

- Care was taken to select appropriate RF cables for receive and transmit sections to achieve maximum sensitivity and ERP respectively. Though waveguide sections, in general, are preferred to achieve lower loss in case of high power Txs, it was found that co-axial cables provided a better compromise between achievable throughput delay Vs RF insertion loss as it was feasible to route cables over shorter distances than waveguides.

- The interoperability of various subsystems of the Defensive Avionics and also with other onboard systems was studied. A matrix of various Txs and Rxs was prepared and possible interferences assessed (Table-2). Thereafter compatibility scheme was worked out for the management of onboard transmitters and receivers.

- High power tests under controlled conditions were conducted for short durations after installing all the onboard avionics equipments in an open range (Fig.5). Interference was observed between RWR and EA systems and onboard equipment like Doppler Navigation and Radio Altimeter. The interference was contained by insertion of notch filter, LPF, selective BRFs, selective blanking, look through and blocking transmission at PFM designated frequencies.

**Post Installation Checks**

After installing the equipment on aircraft, as part of post installation checks, the following procedure was adopted:

- Physical inspection of interconnection between Tx/Rx and antennae
- Insertion loss and VSWR checks of RF cables
- Monitoring of Power on sequence, standby indication and BIT
- Injection of RF signals in the RWR and checking the receiver sensitivity and dynamic range with a custom made Test Rack (TR)
- Injection of RF signals in the EA system and checking the Rx sensitivity and Tx output power and its spectral quality with TR
- Checking the system performance in all modes of operation as per a test PFM
- Finally, testing of the system with a Field Signal Generator (FSG) to check the installed performance/health of the full system.

**Table-2 : Interference Matrix**

| Tx \ Rx | LB Pod S,C Band | HB EA System C,X,Ku Band | RWR S,C,X Ku Band | RAD ALT C Band | DOPPL NAV (Ku) | IFF (L) |
|---|---|---|---|---|---|---|
| LB Pod S, C Band | Y (F) L/T | Y (H) LPF in LB | Y (F & H) L/T | Y (F & H) Block Tx | N | N |
| HB EA System C,X,Ku Band | N | Y (F) BRF | Y (F) Blanking Pul | N | N | N |
| RAD ALT C Band | N | N | Y (F) On ground only | N | N | N |
| DOPPL NAV (Ku) | N | Y (F) Notch filter | N | N | N | N |
| IFF (L) | N | N | N | N | N | N |

Y - Yes, N - No, F- Fundamental, H- Harmonic, L/T - Look Through, BRF - Band Reject Filter

The aforementioned procedure enabled satisfactory installation and integration of the Defensive Avionics Suite and ensured proper operation in flight.

## Pre Planned Product Improvement (PPPI) Features

The design of the Defensive Avionics Suite was made amenable to planned improvements. As an example the RWR was upgraded with a high performance processor PCB to significantly enhance throughput and higher sensitivity was achieved with a drop in replacement of RF front end receivers with higher sensitivity units and by updating Operational Flight Program Software but without any modification to the aircraft. The EA components likewise could be upgraded to incorporate DRFM technology for RF signal storage and retrieval in both HB and LB segments to implement coherent ECM. Another built in feature is the capability to extend the frequency coverage to mm wave band by an add-on mm wave up down converter module and a mm wave transmitter.


## Summary

The need for a Defensive Avionics Suite considering the threat scenario encountered by a strike aircraft is described. Design goals and an architecture suitable for this application is presented. The Defensive Avionics Suite developed by DARE, DLRL and ADE is described. Problems encountered during system installation and integration on the fighter aircraft are also brought out. Some of the Pre Planned Product Improvement features in the system are described. The development of this Defensive Avionics suite marks a major indigenous effort in up-gradation of a fighter aircraft to enhance its survivability and has led DARE to undertake development of next generation system.


## References


1. Lt. Col. Richard E. Fitts., "The Strategy of Electromagnetic Conflict" , Chapter 3, page 42, Peninsula publishing, California 94022.


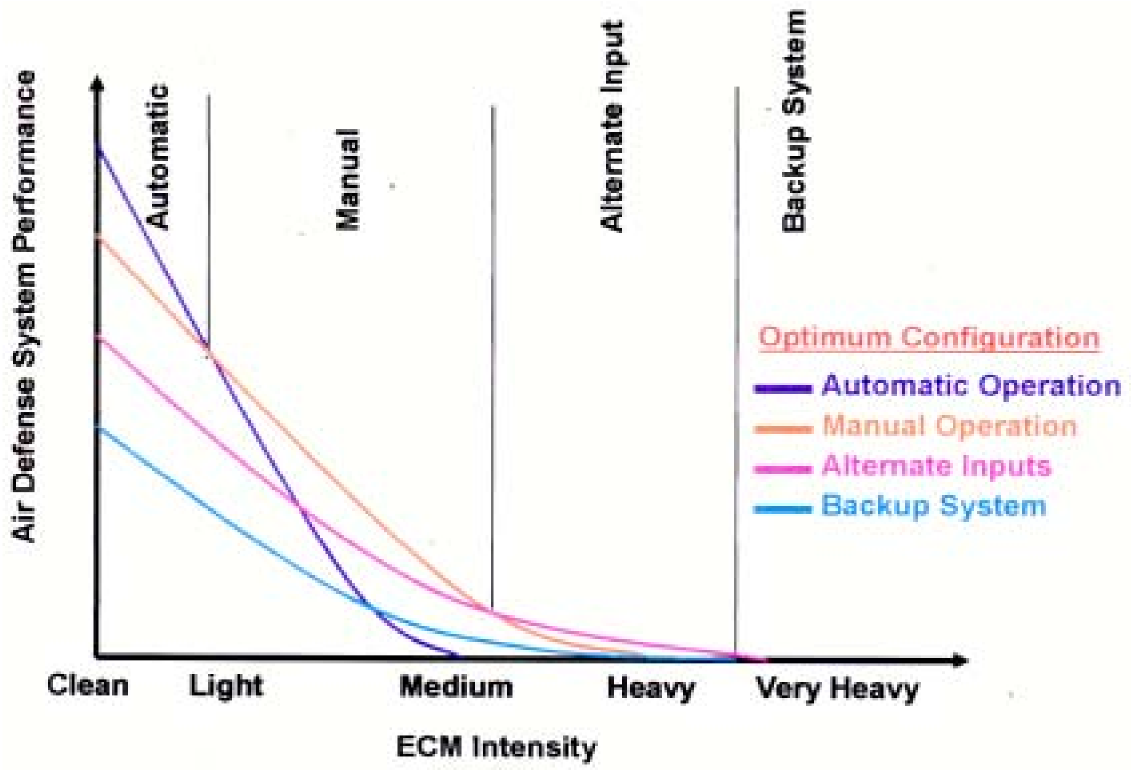


*Fig. 1 Air defence system degradation with ECM intensity*

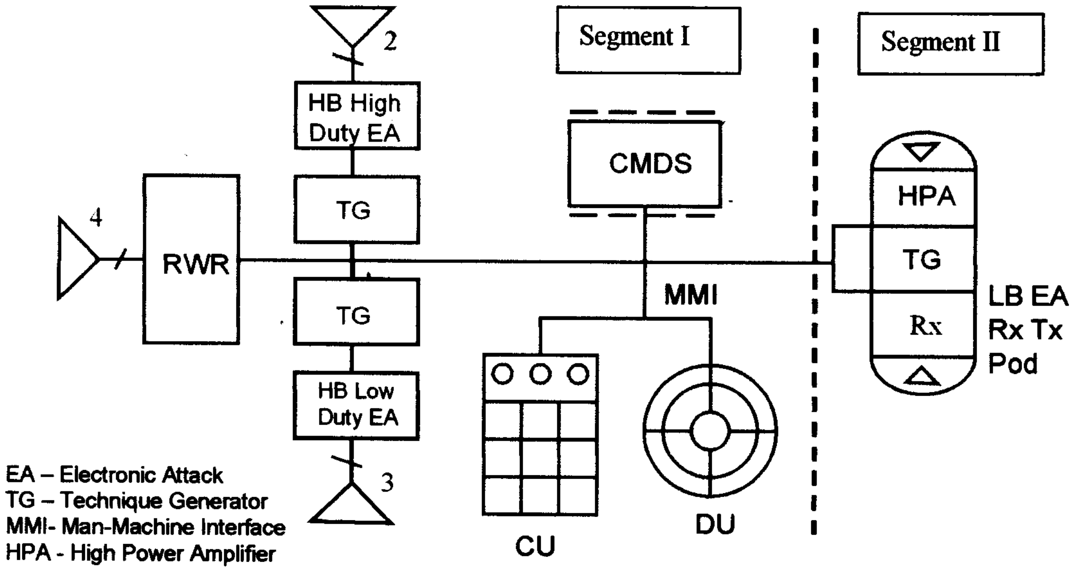


*Fig. 2 Defensive avionics architecture*


*Fig. 3 Defensive avionics LRUs*

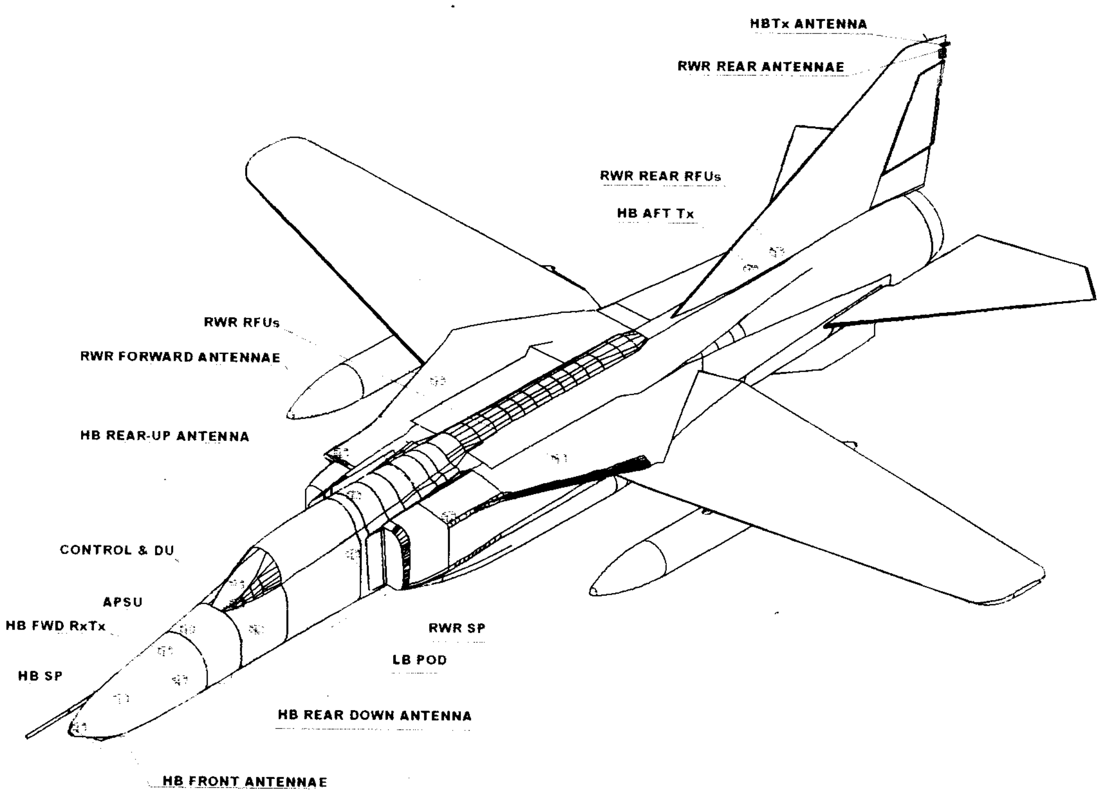


*Fig. 4 Defensive avionics LRUs installation scheme*

*Fig. 5 Integration tests on ground*