

# Airborne Multimode Radar Evaluation (Rig Integration and Flight Testing)

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## ABSTARCT

*Airborne Radar Design & Development is a complex process. The integration of its subsystems on ground needs their performance as desired in airborne conditions. It is prudent to carry out Radar's flight testing in a flight test bed for fine tuning various algorithms which are utilized for ensuring the suitability, so that the development goes through smoothly and performance is ensured.*

## I. Airborne Radar System and Modes

Radar transmit electromagnetic energy, analyses the reflected echo for deriving various characteristics of the object. Airborne radar suppose to take care of the effect of the dynamics of own aircraft onto which the radar is mounted and provides information to the user in required form.

Radar consist of subsystem like Exciter (waveform generator), Receiver, Transmitter, Signal and Data Processor, Antenna platform, Antenna, Radar Controller

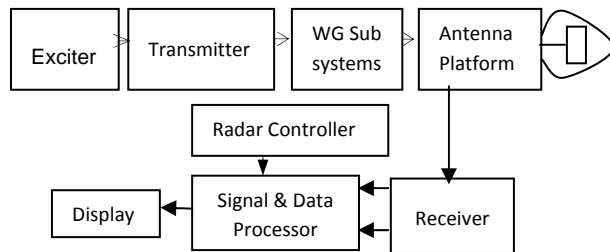


Fig1: Radar Block Diagram

Airborne radar being discussed is multimode Radar. This radar can be operated in different modes suitable for Air to Air (search, Track, Air combat), air to ground (map, search, Tracks) and Air to sea target detection and tracking. During the development process the Radar hardware meeting the requirements is developed. The Radar can be configured for various modes of operation driven by the software resident in the system.

Initially the software required for the basic functionality is developed, followed up by different modes of operation. There is a great need for integration of system and detailed testing of the radar on the ground (test rig). In this development process various sub modes are tested to great detailed and integrated as fully operational modes. As the various modes are getting complete, it is felt that the system need to be tested on an airborne platform to ensure the function as intended.

## II. Need for Airborne testing of Radar on a Flight test platform.

Dynamics of the airborne platform affects the radar performance in many ways. Radar is suppose to take information from various sensors and take action appropriately for example INS (Inertial Navigation System) data will be utilized for Antenna platform stabilization. Aircraft velocity/ acceleration etc are taken into account. Platform motion is another aspect, which can be effectively tested during airborne testing.

Target aircraft maneuvering compound with own aircraft dynamic puts suitability of the algorithms to test. Airborne testing during development helps in understanding the suitability algorithms and their fine-tuning for the system.

Once the basic radar is developed with the hardware meeting present and near future requirement the various functionality/modes can be added to the radar. Flight-testing in these initial stages helps in evolving robust radar. Later on as the more and more features are added, the incremental testing becomes easier. Hence Flight-testing on a flight test platform is essential.

## III. Integration of Radar, support and monitoring system on aircraft

AVRO HS-748 has been selected as the flight test platform. The aircraft nose cone structure is modified for the fitment of radome, which is suppose to be used in the corresponding fighter aircraft. Radar subsystem were mounted on to a rack, which is fitted in to aircraft nearer to the cockpit. The antenna platform along with antenna fitted on to the back plane in nose cone position of the aircraft with in the radome. There is wave guide run between the radome and antenna, which offers loss but enable easy accessibility to radar subsystem. Various support systems like air-cooling, liquid cooling wave-guide pressurization Units are fitted in to the aircraft and interface with the radome. Various other monitoring system, mission computer simulator, Multi function display system, Radar control panel system and flight test Instrument are integrated on to various racks which are mounted in the aircraft.

Other avionics system INS, GPS etc are also with the radar mounted on to these Racks and integrated. To meet power supply requirement of radar and other system an auxiliary power generator system is utilized. The power supply further connected to meet different requirement of radar.

Other system, which helps in coordinating with the controlled sorties target aircraft and check the performance of the radar recorded Ground position system data on target and own aircraft video recording of the radar page on Multi function display, 1553 bus recording digital data recording system are the system Interfaced with radar on aircraft Radar and associated system on aircraft.

Initially Radar is integrated and tested at RIG for functionality, performance safety and after clearance from the flight safety authority, shifted to the aircraft to check the radar in airborne condition. Line replaceable units are inter connected over the 1553 bus protocol and provision has been made to record the communication between the line replaceable units. Multi function display is used for displaying radar page provision has been made to record the radar page on to the video recorder.

Auxiliary power generation system housed in aircraft to generate 115V and 400Hz supply for the line replaceable units, frequency converter and 28v DC generator. Frequency converter converts the 115V 400HZ to 230v 50Hz supply for the industrial personnel computers, measuring, monitoring instrument and recorders.

Safety precaution has been taken while choosing the instrument, personnel computers and fitment of line replaceable units, personnel computers instrument and other support systems so has to with stand the flight maneuverability and dynamics. Offline analysis of captured Bus data, I/Q data and video recording is carried out, which will help in fine-tuning of software, hardware and algorithms

#### IV. Ground testing of radar on aircraft

The radar is integrated along with all other support system and tested on ground. Simulators are utilized for system testing. Once the functionality, performance with simulator with in the aircraft are ensured, further testing is carried out with free space i.e. with target simulated with appropriate parameter at microwave frequency reaching the radar through freespace /Radome/ antenna etc, this ensure the complete chain of radar testing except the airborne testing, In such fielded bite test (FBIT) target simulate to introduce parameter like Range, strength, Azimuth, Elevation and velocity etc.

Target of opportunity is next stage of ground testing were the radar placed on ground to carry out target of opportunity (of the civil aircraft). And the radar operated various modes to check performance against these targets and arranged sorties

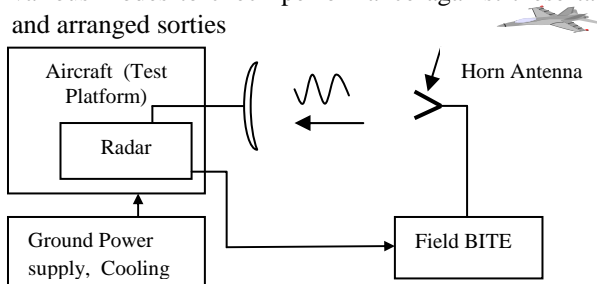


Fig2: Field BITE Setup

#### V. Flight testing

Various clearance by appropriate authorities is ensured before the actual flight testing of the radar these include clearance of the system for development flight testing by Regional center for military airworthy (RCMA), Radar and related system clearance for flight testing by CRI (aircraft), DGCQA and FRRBC (flight readiness review board) constituted by aircraft system house. Detailed Switch ON switch OFF procedure, duties of each radar testing (crew) engineer onboard worked out and discussed and enclosed by a/c support flight test agencies etc.

Detailed pre flight and post flight test requirement /documents/procedure worked out for ensuring proper flight test. Radar test crews were trained on all safety procedure. Three radar test crew along with one coordinator are earmarked for carrying at the flight-testing.

For effective flight-testing various types of target aircraft are selected. Most of the testing envisaged against a small a/c like Kiran trainer aircraft. Appropriate GPS receiver/recorder along with GPS based target-tracking system integrated on to the target aircraft.

#### VI. Radar Flight test cases

Radar flight-testing envisaged in different phases.

Phase – I includes basic radar functionality, low prf, medium prf modes for search, detection and Track while scan (TWS) and Single target tracking. Later phases will take up air to ground, Air to sea and other modes.

In phase-I first block of sorties (about 5) are utilised for basic functionality checks of all the line replaceable units in airborne condition, antenna stabilisation, transmission, reception, different mode transition and display.

Next block of sorties are utilised for radar testing in low prf modes (look up aspect). Kiran, Jaguar, MIG and Taneja aircrafts were used as targets. Initially the target detection was evaluated in low prf 60 deg/sec scan rate with target in tail on, head on aspects.

Fine tuning of the timing signal synchronisation, Constant false alarm rate (CFAR) threshold processing etc functionality was ensured.

Next was low prf mode with other scan rates checked. After ensuring proper scan/search mechanisms, detection, tracking (TWS) was initiated. The target tracking was evaluated in all the aspects. The issues in track initiation, synchronisation of tracks, track brakes were fully evaluated.

Medium prf modes are taken up in next block of sorties. Once the mode transfer and basic functionality of the radar ensured in the medium prf modes, detailed detection, resolving (range, Doppler) issues were evaluated. The issues of range resolving, target split, Doppler filter processing are addressed.

Initially look up aspect with target in tail on, head on are evaluated. Side lobe blanking issues were addressed.

Performance in look up is established Track While Scan in look up aspect evaluated.

Next look down has been taken up, ground clutter, false detection/ CFAR Threshold issues are addressed. Target in all aspects is evaluated for search and TWS.

Tracking algorithm fine tuned for reduction of false tracks without affecting tracking performance of desirable targets in all aspects ensured.

As the system was tested in low prf and medium prf modes successfully the SOP and the Software versions are base lined. The performance of the radar is evaluated in all the low and Medium prf with different scan rates/ scan zones in all the aspects evaluated, results summarized.

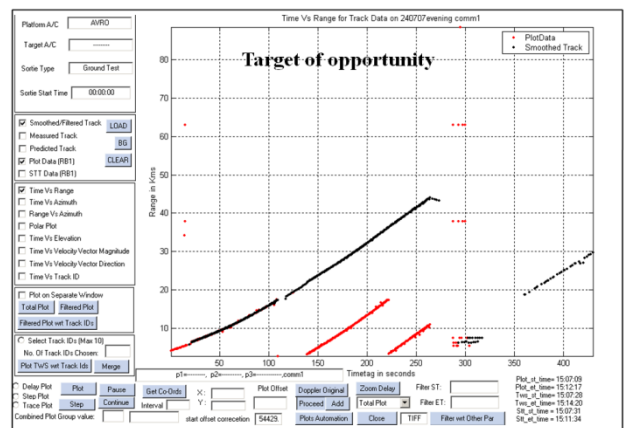
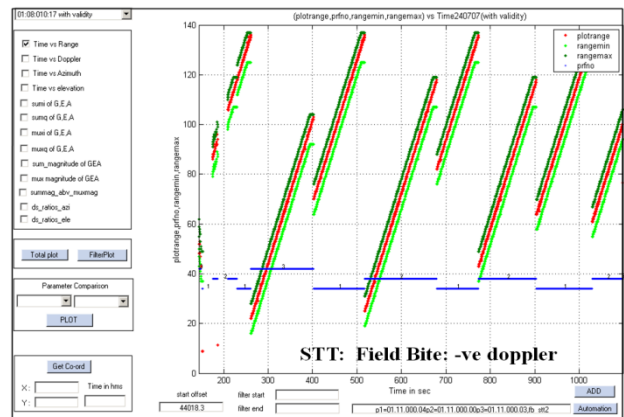
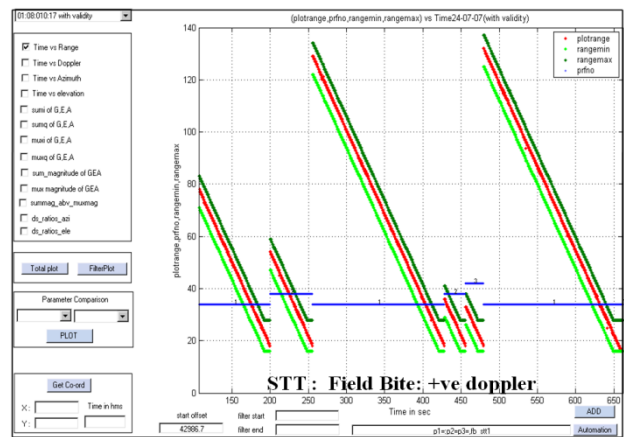
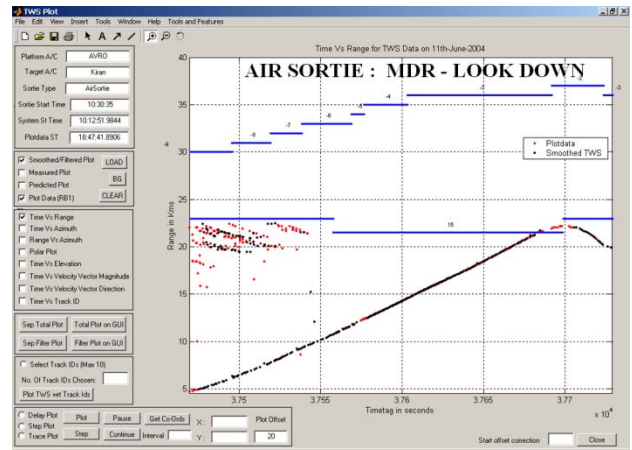
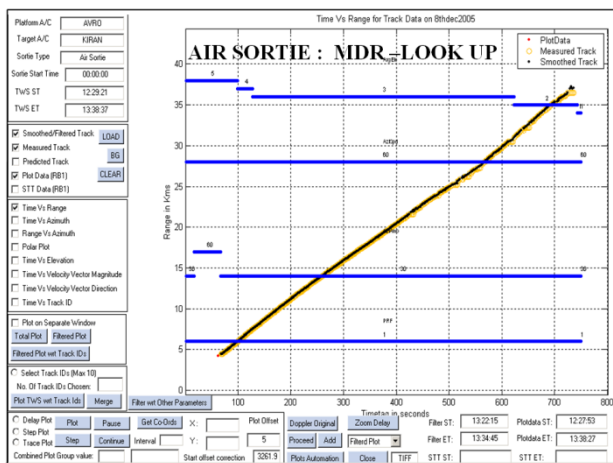
Next mode to be integrated for the flight testing was single target tracking. In this Monopulse tracking techniques using both sum and difference channel signals are utilised.. After completing S-curve computation & calibration, detailed testing with Field bite, Single Target Tracking (STT) testing against targets of opportunity carried out.

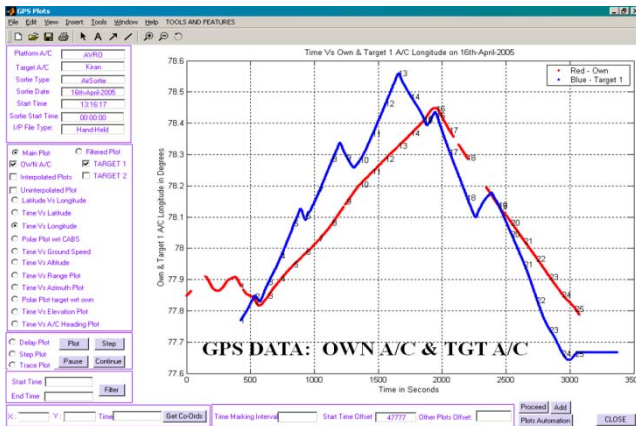
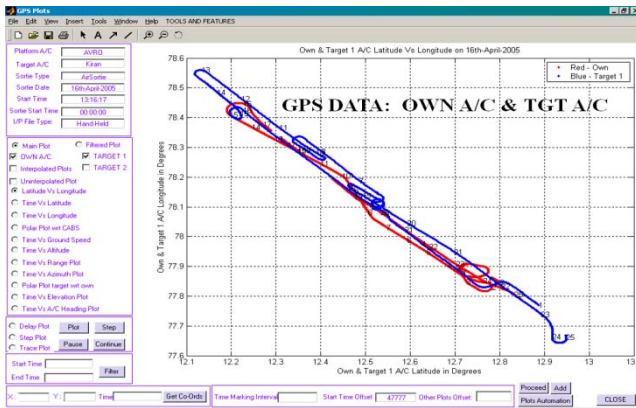
Flight testing of Single Target Tracking (STT) taken up with Kiran aircraft as target. Initially tail on aspect was tested. Mode entry, Single Target Tracking Lock and tracking was checked. Detailed analysis carried out and reasons for lock break diagnosed and algorithms and software. Single Target Tracking with manoeuvring target also evaluated.

Further testing to improve Single Target Tracking and other modes of Air to ground and Air to sea are to be taken up for flight testing after successful implementation and testing.

### VII. Results

The results shown below are Air sorties, Ground sorties, Field bite checks and Target of opportunity.





Experience (on Hardware and Software), Leading and Managing Teams & Projects of various complexities. 20+ years of Design, Development, Integration and Testing experience of Avionics, Radar and Airborne/Ground Applications. Handled Areas like Radar Data Analysis, Embedded and Microprocessor Systems, Analog, High Speed Digital and Mixed Signal Circuits, High speed Digital Data Recording systems, CPLD Designs, Power Supplies, Test Rigs, Automatic Test Equipments and Simulators, Flight Test and Flight Test Instrumentation.



P.S.Krishna Kumar obtained M.Tech IIT from Khargpur. And he retired as a General Manager of SLRDC, HAL, Hyderabad. He has rich experience in Precession approach Radar, Air route surveillance Radar, Data link, Airborne Radar design & development, Radar Testing on ground and flight, Design & development of Radar Rigs,

**Conclusion**

The results shown are for live targets like Air sorties, Ground sorties, Field bite checks and target of opportunity

**References**

- [1] Introduction to Airborne Radars, Second edition, George W. Stimson
- [2] Radar Handbook, Editor in chief, Merrill I. Skolnik, Second edition.

**Bio data of authors**



Sudhakar.J obtained B.Tech Degree in Electronics and Communication Engineering from Sri Venkateswara University Tirupati in 1998.

He joined as a Engineer in Hindustan Aeronautics limited (HAL), Hyderabad in 1998 and has been working in Airborne Radar design & development, Radar Testing on ground and flight, Design & development of Radar Rigs, Designs & development of Solid State Digital & video data recording systems and Radar data analysis. His area of interest is FPGA, Tiger Sharc processors, Blakfin processors. Radar Flight testing.



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