Testing Philosophy for AESA base Radars using Airborne Radar Test Bed

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Abstract

The Airborne Radar Test Bed (ARTB) is a recently operational instrumentation system containing a closed loop tracking, sensor with the capability to record high fidelity signals pertaining to Radar phenomenology, target scattering characteristics, and acquisition and tracking performance. The unique capability of the test bed is used to collect data and develop computer models for evaluating and predicting airborne radar performance. The test bed is also designed to support the development of advanced radars and to demonstrate their capabilities in flight. The objective of this methodology is to provide a detailed testing procedure for the purpose of planning and conducting system level testing of advanced Airborne AESA based radars. This paper also describes the AESA Radar test with a focus on test design, experimental execution, analysis and evaluation of the integrated system.

Keywords: AESA, Radar, ARTB, RTS, DES

I INTRODUCTION

Major problems in airborne radar design are target-detection sensitivity and the effects of ground clutter. The low radar cross section of weapons such as cruise missiles and future fighter and bomber aircraft, as well as the ability of modern targets to fly at low altitudes, makes the airborne radar detection problems even more difficult. These problems combine to present stressing challenges to current Active Electronically Scanned Array (AESA) based Radars [1][2]. The AESA Radar [3] can switch beams almost instantaneously from one azimuth position to another azimuth position without scanning through the in-between region.

LRDE has undertaken a significant effort to help solve these airborne radar problems. The central element in this effort is the Airborne Radar Test Bed (ARTB), a flying instrumentation system that carries a closed-loop tracking Radar and also records high-fidelity signals related to radar phenomenology (clutter, multipath), target scattering characteristics, target acquisition and tracking performance [4][5]. The purpose behind the development of these capabilities is to collect data and to develop computer models that will assist in the design of future airborne radars and in the prediction of radar performance. Future radars will require higher sensitivity and more effective clutter rejection. The system architecture of the Airborne Radar Test Bed was selected to address this set of radar problems.

Ground Clutter

Even if the radar possesses enough sensitivity, the ground clutter can limit performance by masking the target return. Fig 1 illustrates the clutter environment as viewed by the radar. The specific case shown is for AESA radar with pulse-wave illumination. For outbound targets (the tail chase scenario), ground clutter seen through the antenna side lobes directly obscures the target return. For inbound targets, the target return competes with the noise sidebands. Fig 1 indicates that the AESA based airborne Radar is more capable of detecting targets in the incoming target region than in the outgoing target region. In this paper testing philosophy of AESA based radars is proposed using Airborne Radar Test Bed.

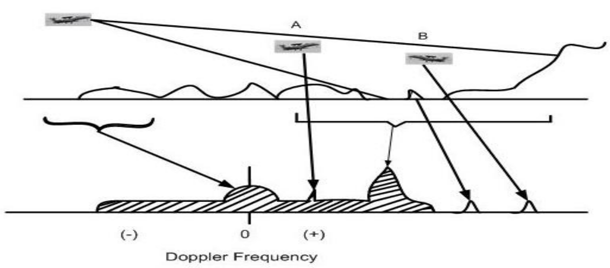

Fig. 1. Clutter spectrum for an airborne radar

II AIRBORNE RADAR TEST BED

Fig 2 shows the Airborne Radar Test Bed that is designed to support investigations into the problems described in the previous section. The test bed represents a captive-carry concept. A principal advantage of a captive-carry experiment is that it allows operation in the actual real-world environment and offers the possibility of repeatable trajectories and systematic profiling. A specific advantage of the Airborne Radar Test Bed is that using a dedicated passenger jet offers room for high-fidelity instrumentation and recording with operator interaction.

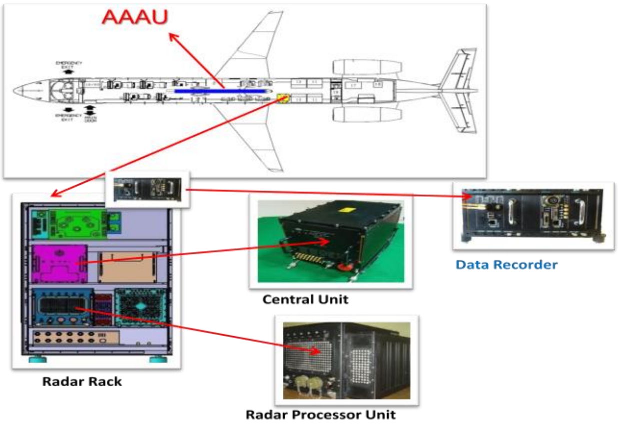

Fig. 2. Principal elements of the Airborne Radar Test Bed

Overview of Test Bed Hardware

Fig 2 shows the major elements of the Airborne Radar Test Bed. The principal payload of the Airborne Radar Test Bed is the Active Array Antenna Unit (AAAU). The other payloads are Central unit (CU), Radar processor unit (RPU) and Data recorder unit (DRU). The AESA Radar tracks targets and provides target-angle, range, and range-rate information in real time.

III METHODS FOR EVALUATING RADAR PERFORMANCE

The first step in development of a radar system to meet a given performance specification is to interpret this specification in terms of subsystem design parameters. This interpretation is performed by the system engineers. During development and assembly of the prototype radar, testing is carried out by the system designers on critical components and subsystems to determine that these portions of the system supports the roles assigned to them by the interpretation of the system specification.

Following successful testing of individual subsystems, the radar is assembled into an operating prototype system, on which testing is performed at the development laboratory. These tests may include operation in the physical environments covered by the specification and limited tests of performance. However, the ability of the radar to meet its over-all system performance specification can only be evaluated by tests of the entire system in the field environment, which includes a realistic electronic environment (e.g. moving targets, clutter reflections, interfering signals, and possibly attempts at ESM intercept of the radar signals).

The methodology for system-level testing and evaluation of AESA based Airborne radars are discussed below.

Captive Carry

Captive-carry experiments carry an AESA based Radar on the Test bed. Captive-carry flights can operate against manned target. This approach offer the possibility of more exhaustive testing in more varied environments, and it is especially useful in the development of large databases (e.g. ground clutter).

Radar Target Simulator

The Radar Target Simulator (RTS) is a hybrid radar target and jamming simulator. Its purpose is to simulate physically targets skin reflections, ground reflections and electronic counter measure (ECM) techniques as seen by the radar receiver according to the radar emission signal.

This evaluation method uses a bench setup to inject signals into radar Central unit. Software simulation sequences the signals through RTS hardware. This approach can be as elaborate as placing complete radar in a lab setup. This type of test relies on the accuracy of the assumptions made in the software model. This approach is useful in exercising and evaluating specific functions of the radar hardware & software. Fig 3 shows major elements of RTS.

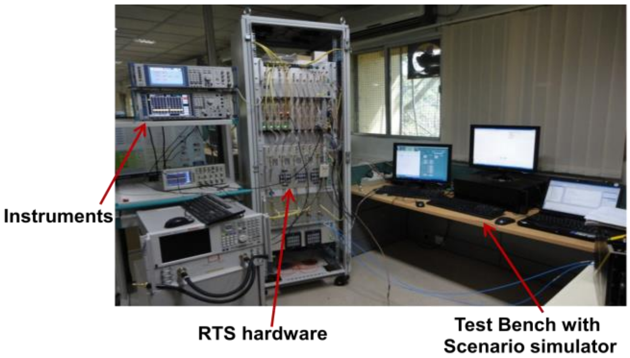

Fig. 3. Major elements of Radar Target Simulator

Computer Simulation

Computer simulation is the most flexible analysis technique because it can be extrapolated to cases that have not or cannot be tested. It is also likely to provide the least fidelity of the listed methods because the results depend on the accuracy of assumptions used in the software model. The validity of a computer simulation is enhanced greatly by infusions of the data and experience gained from the captive-carry tests. Fig 4 shows major elements of Digital Target and Environment Simulator.

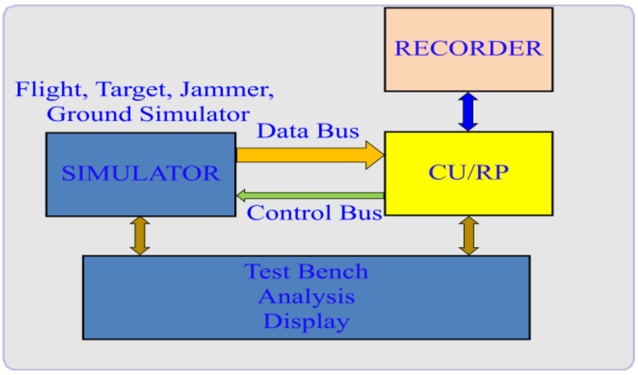

Fig. 4. Block Diagram of Digital Environment Simulator

Fig 5 shows the interface diagram of the Digital Environment Simulator (DES) System. Computer-generated simulated targets are superimposed on the environment [6][7]. It has capability to simulate flight trajectory and different types of jammers.

Linkage among Test Methods

Computer simulations support algorithm development and detailed performance predictions. These computer simulations support system verification, validation and pre-flight preparation.

RTS permits closed-loop evaluation of the entire signal processing chain (both analog and digital). Furthermore, the desire to reduce live testing through extensive use of simulation necessitates RTS based simulations. The generation of complex high-fidelity radio frequency (RF) in real-time requires significant computing throughput.

Captive-carry experiments permit the evaluation of the entire radar in a real-world environment. Captive-carry flights can operate against manned targets. In these flights, test bed operators fly in the cabin along with pilots. The data obtained through Captive-carry experiments is applied to the development of software models of radar performance, from phenomenology models (clutter, target radar cross-section dynamics) to aircraft fly-out models.

Computers and Data Recording

Fig 6 is an interface diagram of the primary computers of the test bed. The yellow area in the figure indicates the digital systems. Mission System Controller (MSC) is the aircraft computer that controls the test bed systems. It coordinates and provides the primary operator interface for the test bed. The measurements described below were performed in civilian airspace over Bangalore, rather than at a test range.

The test bed velocity was kept low (150 m/sec) to extend data recording and to simplify pilot procedures in these initial exercises. The AESA radar built to support the test bed provided a Pulsed illumination waveform. The signals in the following figures were received by the AESA Radar antenna through the monopulse sum beams. Fig 7 shows a plot of the received Doppler spectra as a function of range cells. Signal intensity is color coded as indicated; red represents the strongest signals. The wide bright band in the center corresponds to the ground clutter seen by the AESA radar antenna.

IV CONCLUSION

This paper has developed a methodology for airborne radar system testing and evaluation which organizes the test procedure into laboratory-type testing, or closed-loop tests, to characterize system performance in a fine-grain sense, and field test to benchmark major system performance measure in a real-world environment. Airborne Radar Test Bed represents a powerful tool for investigating AESA based Radar performance. The ability to collect high-fidelity data in a repeatable and systematic measurement program makes the test bed especially valuable for investigating advanced radar concepts and for developing signal processing schemes. The test bed demonstrates the basic functionality required for its mission, from the proper performance of all sensor systems, operating modes, and data recording to the execution of clutter and target intercept measurements.

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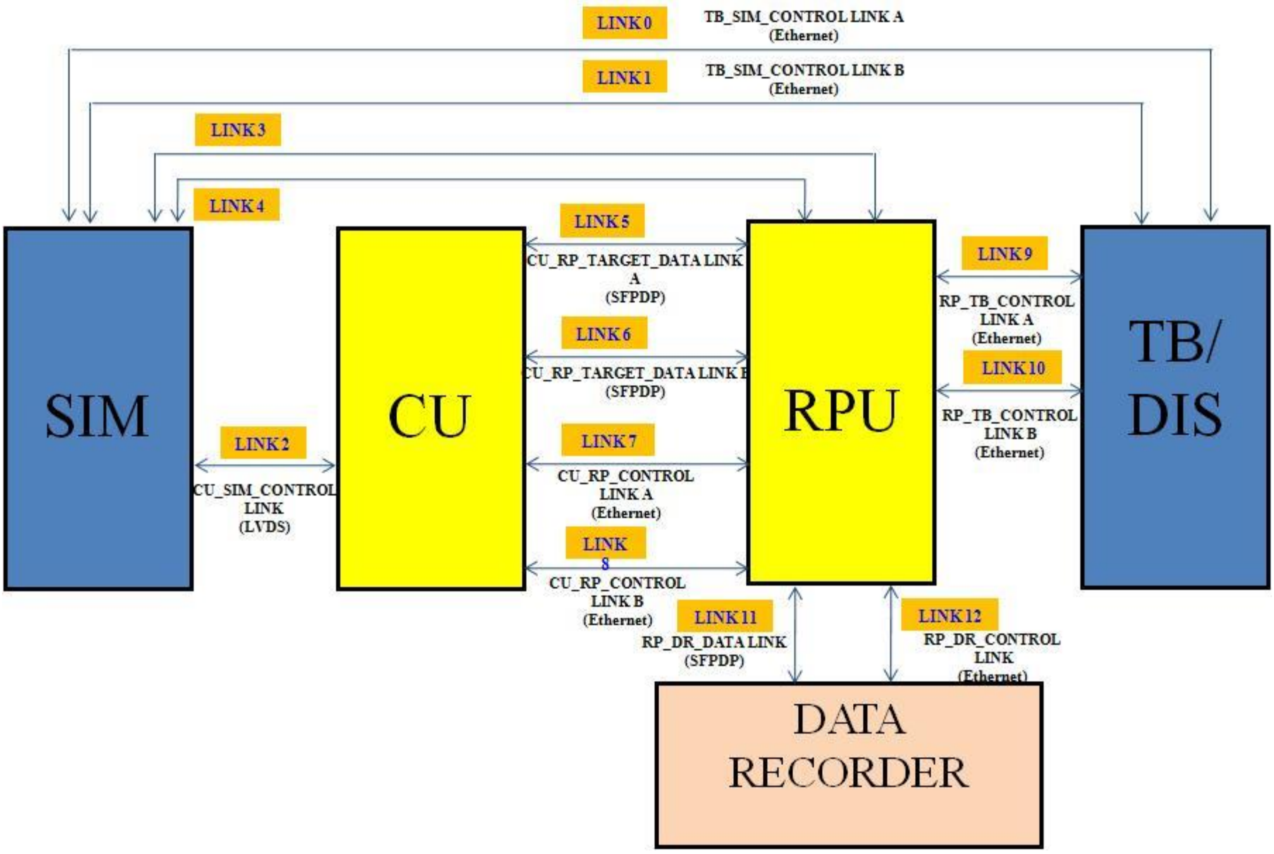

Fig. 5. An Interface Diagram of Digital Environment Simulator

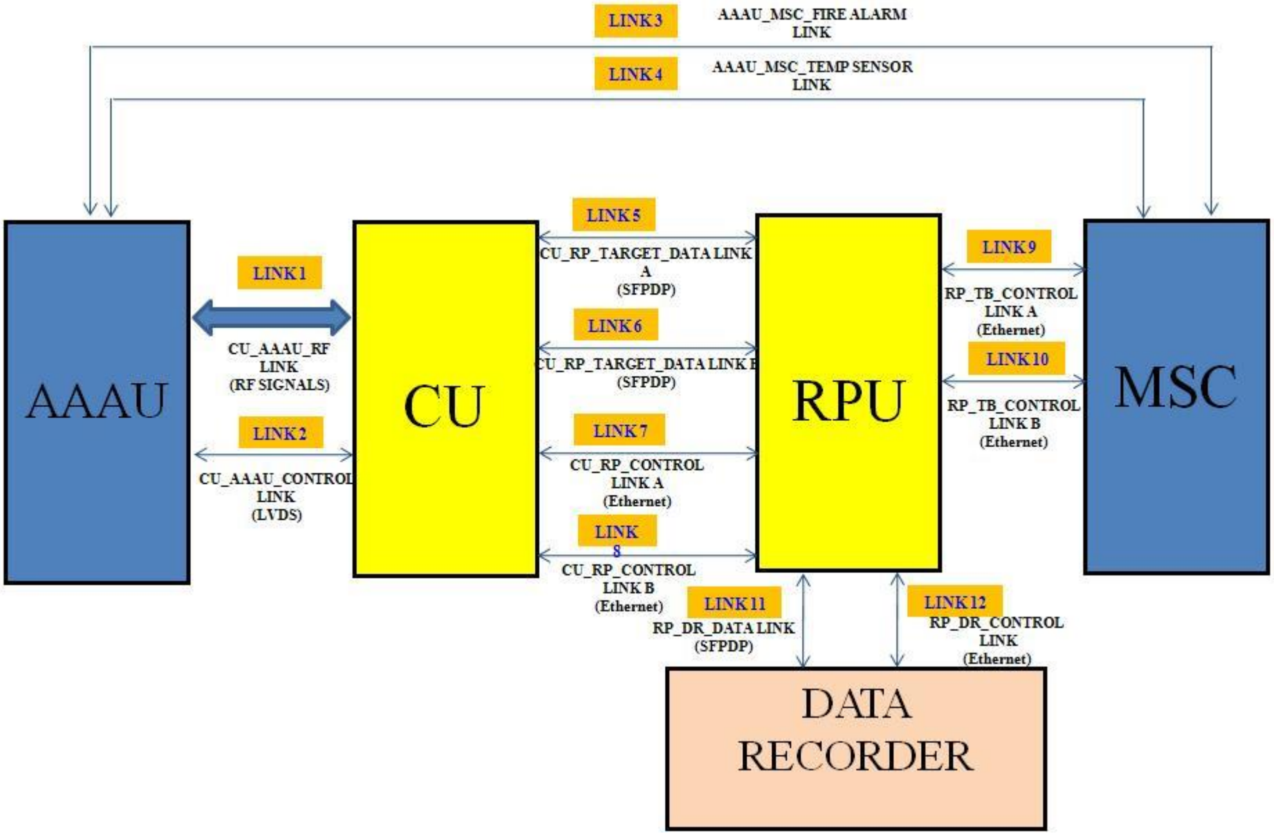

Fig. 6. An interface diagram of the principal test bed computer systems. MSC coordinates, and represents the primary operator interface for controlling the test bed systems.

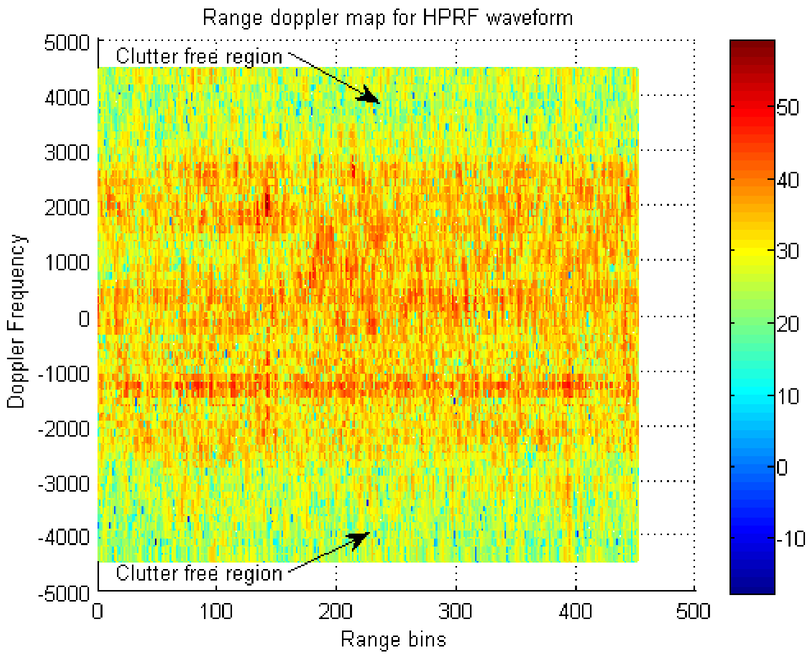

Fig. 7. The Range Doppler map. The bright stripes are ground clutter seen through the sidelobes of the antenna