Airborne Radar Desktop Trainer

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ABSTRACT

Evolving computer technology now provides a platform powerful enough to implement a Digital Radar Landmass Simulator (DRLMS) on a personal workstation. This paper describes the technology and operation of such a device and its application, which is proving most suitable for desktop training. The Airborne Radar Desktop Trainer (ARDT) system is capable of providing all airborne radar modes, including both air-to-air and air-to-ground radar modes; particularly Real Beam Ground Map (RBGM), Doppler Beam Sharpening (DBS), and Synthetic Aperture Radar (SAR). It operates in real-time with fidelity that meets or exceeds that of larger trainers. An ARDT system provides controls that are similar to, and displays that are near replicas of, the actual aircraft hardware. A configuration editor allows the user to modify various radar parameters from their baseline values (e.g., range scale, antenna beamwidth, etc.). A host emulator provides control of the environment, ownship, and targets. The ARDT runs on personal workstations such as the Silicon Graphics O2 and the standard Windows NT PC, and thus provides broad availability to a new and revolutionary training capability.

Traditional radar training takes place in the classroom or on large training devices. The classroom training is mostly limited to theoretical aspects of radar operation and does not entirely prepare the student for actual radar operation. Training on a large training device such as a Part Task Trainer (PTT), Operational Flight Trainer (OFT), or Weapon System Trainer (WST) equipped with a Digital Radar Landmass Simulator (DRLMS) is effective in hands-on operation, but is quite expensive and frequently available only on a limited basis. The ARDT supercedes many aspects of both classroom training and training on large training devices. It provides an intermediate training step between the classroom and large training devices. Thus it provides more cost-effective and more readily available solutions for training radar operators and aircraft pilots who perform radar tasks. The ARDT is also used to provide additional insight to pilots and engineers involved in radar test and evaluation (T&E) activities. And the ARDT is also used for engineering analysis of new radars, providing objective and subjective performance assessments to the radar design engineers.

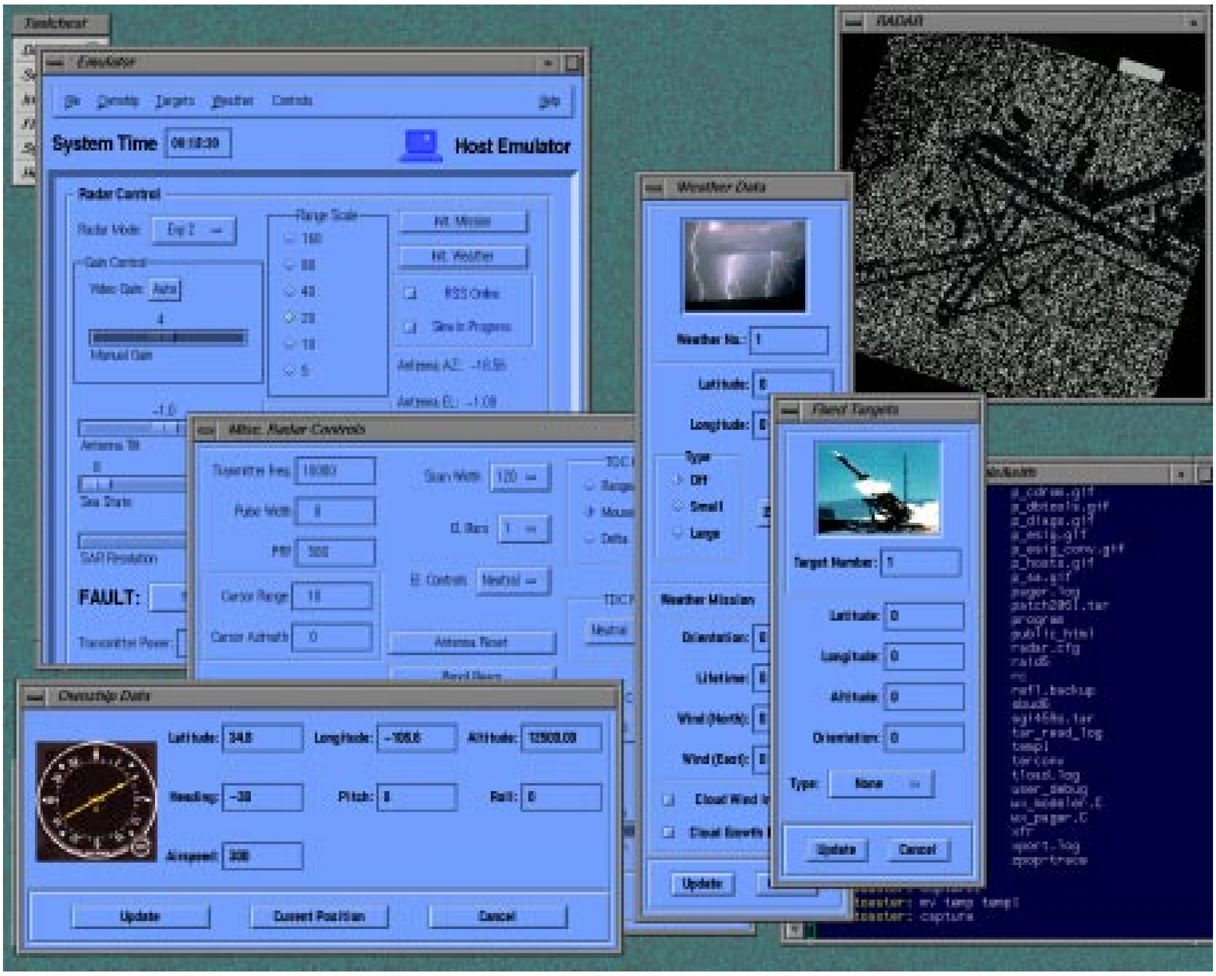
Introduction

Airborne radar simulators (and more specifically, DRLMS) have been around for nearly fifty years. They have evolved from large, hardware-intensive systems costing millions of dollars per unit, to software-intensive solutions hosted on general-purpose workstations providing much more cost-effective solutions.[1] Until recently, however, the principal application continued to be sensor subsystems in large training devices such as a WST. The evolution of computer technology now makes it is possible to build a fully capable DRLMS hosted on a small personal workstation or a PC. Camber Corporation has developed such a system and it is called the Airborne Radar Desktop Trainer (ARDT.) We can now demonstrate this DRLMS capability to replicated a typical multimode airborne radar such as the F-16 AN/APG-68 on a 233 MHz Pentium II with 128 MB RAM, 2GB disk, and standard graphics adapter. This new and revolutionary capability opens up a variety of exciting future training opportunities.

The typical display format is shown in Figure 1. Since this is a Windows-based system, the user can customize the display to specific purposes by selecting, positioning and re-sizing the appropriate windows. Most of the windows are static displays of controls, parameters, etc. They allow the user to operate anywhere within a gaming area that is typically 250 nmi by 250 nmi in size. The radar display is dynamic; it scans according to the radar scan rate. The display is a nearly exact replica of the actual radar display (resolution, dynamic range, color, shades of gray, symbology, etc.) The user has complete control of the ARDT system and can change the environment, ownship, and targets as desired. Then the radar can be operated to determine the performance for that situation.

Overview Of The ARDT

The ARDT system components are shown in Figure 2. It consists of a radar model that is nearly identical to the radar model that forms the basis for the Camber Radar ToolKit (RTK). A detailed description of this high-fidelity DRLMS is provided in the RTK User's Guide.[2] Nearly all radar modes and functions can be provided by the ARDT; however, the most challenging radar modes are the RBGM, DBS, and the SAR modes. These air-to-ground modes require large databases on disk, large RAM for storage of the local area maps, and significant computer throughput to form the images. For the ARDT, we retain the hybrid RTK database architecture comprised of polygonal format on the disk and gridded format in the RAM. The run-time format of the database is derived from the Open Flight data format, and so is compatible with virtually all visual image generator databases.



Ownship Data
Latitude: 34.8
Longitude: -106.6
Altitude: 12500.00
Heading: -30
Pitch: 0
Roll: 0
Airspeed: 300

Misc. Radar Controls
PRF: 500
Cursor Range: 10
Cursor Azimuth: 0
Scan Width: 120
El. Bars: 1

Weather Data
Weather No.: 1
Latitude: 0

Fixed Targets
Target Number: 1
Latitude: 0
Longitude: 0
Altitude: 0
Orientation: 0
Type: None

```
tester: mv temp temp1
tester: capture
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Figure 1. Typical ARDT Display

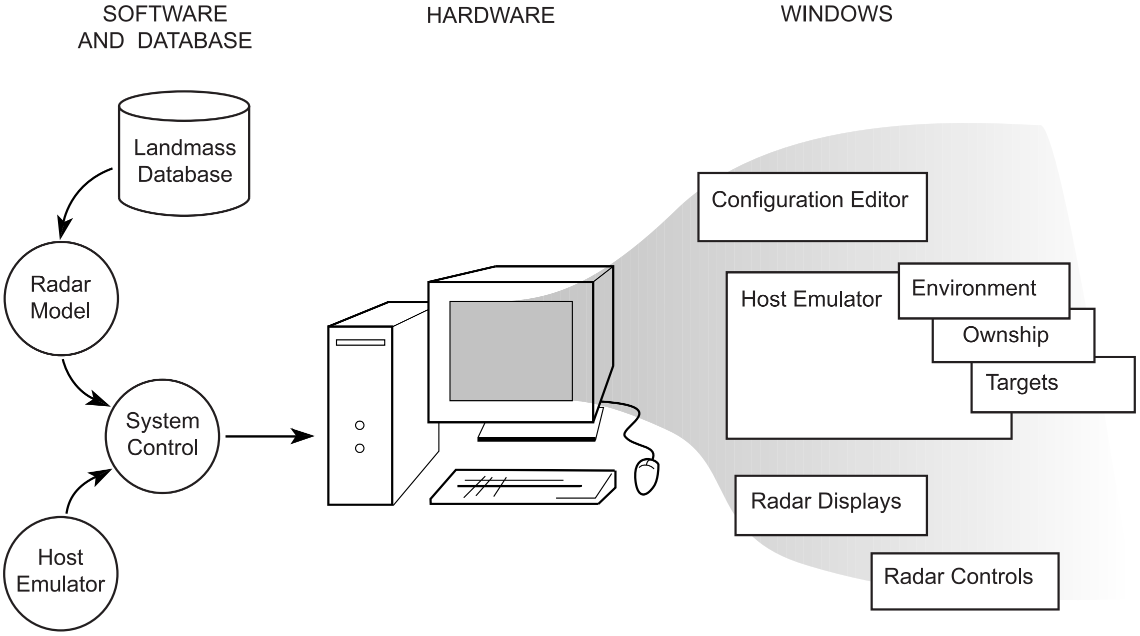


Figure 2. ARDT System Components

Radar Model

The radar model is a complex, real-world, energy level model of the interaction of the emitted radio transmissions and the simulated environment. The software follows an object-oriented design that is based on the physical components being simulated. The model incorporates a detailed three-dimensional database and a realistic treatment of the interaction of the simulated radar with the landmass, targets, jammers, and weather. All appropriate radar phenomena and effects are accounted for in the Camber solution. The model of the radar is partitioned into modules in much the same way that the actual radar is built of line replaceable units (LRUs.) It consists of an antenna, a transmitter/receiver, a signal processor, and interfaces to other systems such as the display system.

The antenna model consists of an antenna servomechanism model and a model of the antenna beam pattern. The servomechanism model simulates the positioning of the antenna in azimuth and elevation. It accounts for the scan mode, antenna dynamics including the interactions of the drive motors, gimbals, and resolvers, and the required coordinate transformations.

The antenna beam pattern is modeled in both elevation and azimuth. In order to model the azimuth antenna pattern and to facilitate sampling the terrain data, the mainlobe of the antenna is divided into several samples. Each sample consists of an array of received power samples at intervals in range. Azimuth beamwidth integration is performed on the samples to arrive at a composite radar signal. This is done by convolving the antenna pattern with the successive samples for each range bin. Then they are modified by the elevation pattern of the antenna. The elevation pattern is modeled by computing the attenuation relative to the antenna peak gain at boresight as a function of angle off boresight. The antenna module provides an output array of signal powers indexed by range and azimuth.

The transmitter/receiver module accounts for the transmit power, pulse width, Pulse Repetition Frequency (PRF), and receiver characteristics. The range bins are formed by convolving the range ambiguity function with the range samples for each range trace.

Receiver functions such as Sensitivity Time Constant (STC) and the Automatic Gain Control (AGC) are also modeled. A noise signal is summed with the radar returns to model the background interference in the receiver front end. The strength of the noise signal is dependent upon the receiver bandwidth, noise figure, etc.

The signal processor module performs additional radar signal conditioning as required for certain modes such as the Single Target Track (STT), Ground Moving Target Indicator (GMTI), and Ground Moving Target Track (GMTT) modes. Key areas include target detection, target parameter measurement, and target tracking. Target detection utilizes a floating threshold based upon total interference (i.e., noise, clutter, and jammer) power within a defined region in range and/or Doppler frequency. As a result of performing actual detections on raw signal data, realistic operation of the radar simulation is ensured. Target parameter measurements are created based upon actual values perturbed by errors according to the signal-to-interference ratio and these measurements then drive the tracking filters. The trackers are implemented with algorithms similar or identical to those of the radar, since we contend that it is usually impractical to model a tracker such as a Kalman filter.

The environment module accounts for propagation of the RF signal through the atmosphere and its interaction with the land, sea, etc. Signal power due to landmass returns, targets, and sea clutter are calculated separately and then combined to derive the received signal strength for each range bin. These equations determine the radar signal propagation, including free-space loss, atmospheric attenuation and system losses. The received power due to landmass returns is calculated and the strength of the landmass returns takes into account the reflectivity of the landmass and any grazing angle effects due to the radar beam incidence angle. For each bin that encounters a non-zero rainfall value, both rainfall attenuation and backscatter values are determined by accessing a look-up table that contains data relating the rainfall rate to the reflectivity and backscatter at the frequency of interest.

The high resolution data required to support DBS and SAR modes is generated on demand at any commanded position. This makes generation of high resolution radar images over large areas possible without requiring unreasonable amounts of disk storage or impossible disk transfer rates. An advantage of this hybrid approach is that the ARDT does not utilize "High Resolution Patches" or "Local Activity Regions" in the conventional sense.

All of the following radar phenomena and effects are accounted for in the radar model: shadows (terrain/ features/ target masking), shadowless objects, range and atmospheric attenuation, pulse length effects, refraction and earth curvature, far shore brightening, corner reflectors, aspect effects (terrain, features, targets), surface material effects (reflectivity, directivity), angle-of-incidence effects, glitter (glint), antenna pattern and sidelobe effects, sea state, weather and chaff effects, seasonal effects, multipath effects, and doppler effects

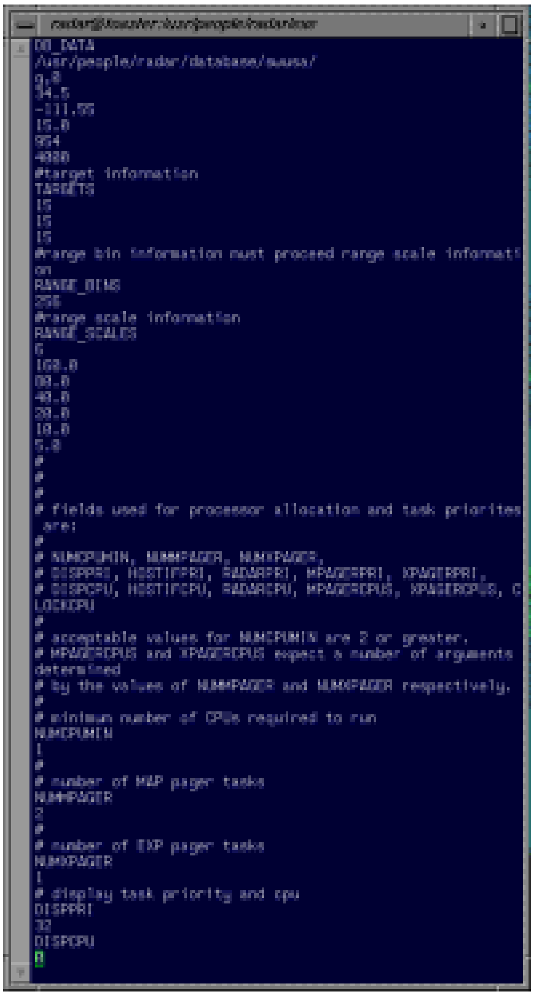
The following are some of the radar characteristics that the ARDT can configure, control, and simulate: antenna sweep rates and sector widths, antenna beam pattern horizontal and vertical, antenna direction and travel, antenna gimbal limits and turnaround, display range, sampling rates, PRFs, receiver noise, receiver transfer function, scan conversion effects, geometric distortion, radar map gain, range and doppler processing, radar coast processing, track through the notch processing, automatic gain control (AGC), sensitivity time control (STC), fast time constant (FTC), motion compensation/ inertial stabilization, symbology, situation awareness cues (e.g. cursor, etc.), etc.

Configuration Editor

The ARDT is reconfigurable by radar parameter specification prior to runtime. All of these parameters are stored in a configuration file such as that shown in Figure 3. Examples include the range scale values, range resolutions, scan rates, etc. Then during runtime the user selects the desired value of parameters from the radar control pages.

Host Emulator

Normally, a DRLMS is a major subsystem of a larger training device such as a Weapons System Trainer (WST). The WST contains a host computer that runs the aircraft aerodynamics model and numerous subsystem models such as the inertial navigation system.



```
DB_DATA
/usr/people/radar/database/auusa/
9.0
34.5
-111.55
15.0
954
4000
#target information
TARGETS
15
15
15
#range bin information must proceed range scale informati
on
RANGE_BINS
256
#range scale information
RANGE_SCALES
6
160.0
80.0
40.0
20.0
10.0
5.0
#
#
#
# fields used for processor allocation and task priorites
 are:
#
# NUMCPUMIN, NUMMPAGER, NUMXPAGER,
# DISPPRI, HOSTIFPRI, RADARPRI, MPAGERPRI, XPAGERPRI,
# DISPCPU, HOSTIFCPU, RADARCPU, MPAGERCPUS, XPAGERCPUS, C
LOCKCPU
#
# acceptable values for NUMCPUMIN are 2 or greater.
# MPAGERCPUS and XPAGERCPUS expect a number of arguments
determined
# by the values of NUMMPAGER and NUMXPAGER respectively.
#
# minimum number of CPUs required to run
NUMCPUMIN
1
#
# number of MAP pager tasks
NUMMPAGER
2
#
# number of EXP pager tasks
NUMXPAGER
1
# display task priority and cpu
DISPPRI
32
DISPCPU
0
```

Figure 3. Excerpt from a Typical Configuration File

The host computer senses all switch/control settings via an electronic interface to the cockpit, runs the Instructor Operator Station (IOS), and drives the DRLMS, Image Generator (IG), etc.

The ARDT host emulator performs the role of a host computer surrogate. It maintains the environment, ownship, and targets. The environment includes weather, jammers, and other environmental aspects that effect radar performance. The ownship position and attitude are maintained by traversing a preplanned flight path. Presence, location, and status are maintained for each target in the gaming area. Furthermore, the host emulator provides radar controls and parameter settings to the radar model.

The host emulator runs from a window on the ARDT display and the main menu is shown in Figure 4. Note the toolbar at the top of this menu that provides pulldown menus for setting ownship, target, weather and other parameters. Some of these additional menus are shown in Figure 1.

Radar Controls

All radar controls are presented as buttons, sliders, etc on windows in the ARDT. All controls are selected via mouse, mouse clicks, and keyboard. The most frequently selected radar controls, such as mode select and range scale, are provided on the main menu of the host emulator, which is shown in Figure 4. Additional radar control pages may be selected and an example of miscellaneous radar controls is shown in Figure 5.

Figure 4. Main Menu

Note that although the radar display is the primary radar indicator, there are some important dynamic parameters shown on the radar control pages. These include, for instance, the instantaneous antenna pointing angle, height above terrain, cursor range, among others.

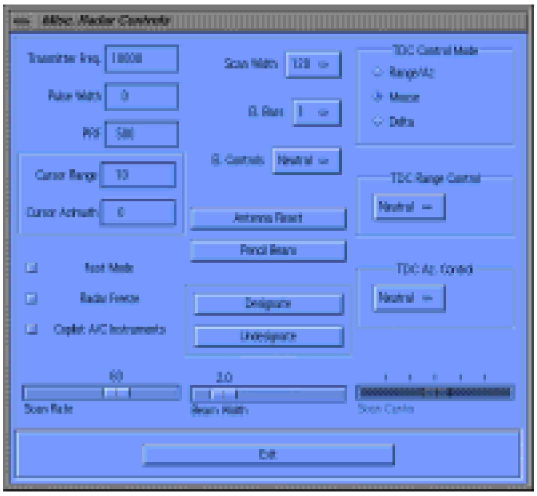


Figure 5. Radar Controls

Radar Displays

The basic radar display for airborne applications is the Plan-Position Indicator (PPI) display, which provides a geographically rectified display of the radar return by scan conversion from R/Θ to X/Y. The PPI display is used for most RBGM modes, scanning DBS modes, etc. A representative example of a SAR image is shown in Figure 6. The ARDT provides this radar display in a window that can be moved by the user to the most convenient position on the ARDT display.

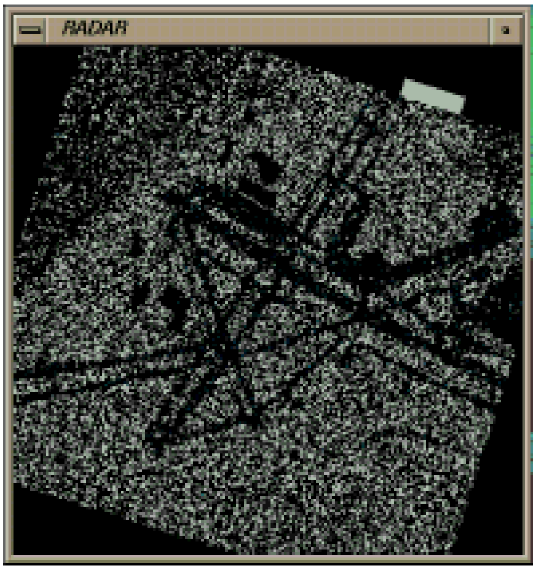


Figure 6. Simulated SAR Image

Applications

The ARDT is currently in use for training and radar analysis by numerous organizations. Its primary applications are operator training, pre-mission analysis for T & E, and engineering analysis. A brief discussion follows.

Operator Training

Traditionally, introductory radar training takes place in the classroom. Unfortunately, many of the radar principles are somewhat abstract and difficult to grasp without further illustration. Furthermore, the classroom training is mostly limited to theoretical aspects of radar operation and does not entirely prepare the student for actual radar operation. The ARDT provides a most effective method for illustrating the operation of the radar. The instructor can provide the student with many workable scenarios in which to demonstrate radar operation and show the expected results. An example is the effect of doppler notch on the ability to locate a ground target depending on the angle of approach. Another example is the ability of a rotor craft to remain undetected by the radar by locating slight below the nap of a hill and thus within the radar shadow.

Pre-Mission Analysis For Test And Evaluation

Flight tests are tremendously expensive, and it is difficult to comprehend the value or meaning of some tests without repeated flights. The ARDT system provides the T&E engineer a method for preliminary evaluation of these tests and a tool for designing the tests prior to execution. A simple but representative example is determination of the maximum detection range of a ground target. The test area can be loaded into the radar database, and then the ARDT system can be used to fly the flight path and determine when the target is occulted, when the target should be detectable, etc.

Engineering Analysis

The transition from a paper design to a functioning radar is a big one, representing risks between perceived and actual results. The ARDT serves as a worthwhile tool to bridge this transition and provide the engineers with feedback and a mechanism for iterating their designs before making major commitments.

Summary

This paper describes the technology and operation of the Airborne Radar Desktop Trainer. This device is most suitable for desktop training. It is capable of providing all airborne radar modes including both air-to-air and air-to-ground radar modes, realbeam groundmap, Doppler Beam Sharpening, and Synthetic Aperture Radar. It operates in real-time with fidelity that meets or exceeds that of larger trainers. An ARDT system provides controls that are similar to, and displays that are near replicas of, the actual aircraft hardware. A configuration editor allows the user to modify various radar parameters from their baseline values (e.g., range scale, antenna beamwidth, etc.). A host emulator provides control of the environment, ownship, and targets. The ARDT runs on personal workstations such as the Silicon Graphics O2 and the standard Windows NT PC, and thus provides broad availability to a new and revolutionary training capability.

About The Authors

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References

[1] Bair, G. L.: “Advances In Airborne Radar Simulation,” Proceedings Of The 9th International Training And Education Conference, April, 1998, Lausanne, Switzerland.

[2] Camber Corporation: “Radar ToolKit User’s Guide,” Document No. RTK-1804-343-002, December, 1996.