ADVANCED GROUND MAPPING RADAR SYSTEMS

A SIMULATION CHALLENGE FOR THE 80's

John D. Stengel, Jr.
Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

ABSTRACT

The role of the airborne ground mapping radar has been dramatically changing over the last several years due to great technological strides in the science of radar design. Great improvements have been made in both the accuracy and resolution of radar systems primarily due to the influence of high speed digital signal processing and the development of synthetic aperature radar design. As a result of the many improvements to both radar system performance and flexibility, the role played by radar systems is also expanding. As advanced radar become part of aircraft avionics systems, the requirement for high fidelity training systems immediately follows. Changes to existing digital radar landmass (DRLMS) specifications will therefore be required. In order to meet the training requirements for advanced high resolution systems both enhanced revisions of current DRLMS systems and alternative technologies may be required.

INTRODUCTION

Digital radar landmass simulation (DRLMS) technology developments over the last ten years have brought the simulated radar system from not much more than a procedural type trainer to a point where world wide mission rehearsal can be accomplished. The current state-of-the-art DRLMS capability permits radar imagery to be generated that, in many cases, is indistinguishable from the actual aircraft radar image. Unfortunately for the simulation community, the state-of-the-art for aircraft radar systems is not static and can be expected to dramatically change over the next ten years. In response to these changes to aircraft radar systems, significant changes and improvements to DRLMS technology will be required.

Advanced aircraft radar systems will become increasingly more capable of generating high resolution imagery. This paper describes the future role of radar systems with particular emphasis on the anticipated changes and additions to DRLMS specification requirements as a result of new aircraft radar system, and upon the potential impact on DRLMS design.

Future Role of Radar

Future radar systems will be called upon to do an increasing number of tasks as the role of combat aircraft expands with new mission requirements while having to contend with more sophisticated enemy defensive capabilities. The following paragraphs examine the new roles and requirements that are currently being identified, and several of the advanced capabilities that are being developed to meet these requirements.

The trend for future advanced radar systems has already been established by the multimode capabilities of the FB-111 and the advanced capability B-52 radar systems. Systems such as these employ not only the basic ground mapping modes used for general navigation but also include special spotlight/offcenter type high resolution modes for weapon delivery as well as terrain avoidance/terrain following modes to permit low level penetration flight. However, performance limitations of older multimode systems are rapidly being reduced on newer systems by virtue of high speed digital signal processors and on-board computer systems which permit a great deal of flexibility to be exercised in terms of how a radar signal can be processed, analyzed, enhanced, and ultimately displayed. As a result of the enhanced flexibility that is inherent to the digital signal processing capability, an advanced radar system need no longer be limited to the basic capabilities for which the system was originally designed. Both new modes and enhancements to existing modes will be possible to add to advanced radar systems without major modifications or redesign. The multimode capability will further be enhanced with the inclusion of the phased array antenna. (1) Antennas of this type will permit rapid changes from one mode to another and precise pointing at desired targets by electronically steering the radar beam without the delays inherent to conventional mechanically scanned antennas. Examples of different capabilities that will be a part of an advanced multimode radar system include conventional real beam ground mapping, enhanced high resolution imagery using doppler beam sharpening, synthetic aperature antenna with signal pulse compression techniques, terrain following, doppler ground speed measurement, air-to-air and air-to-ground target identification, and rendezvous beacon interrogation.

Both existing and future aircraft will be called upon to carry out an increasing number of mission roles and objectives. Bomber type aircraft will be required to accomplish not only the more traditional low altitude penetration and bombing role but also a standoff missile launching role. Although accuracy for weapon delivery has always been a goal, the requirement for high accuracy is continually becoming more critical due to the decreasing vulnerability of many target areas. An inertial navigation system integrated with the aircraft weapon delivery computer is capable of providing the desired accuracy, but only when system initialization and periodic updates have been provided by an accurate sensor source such as radar. A synthetic aperature mode will be capable of providing the desired high resolution input for both direct weapon delivery modes as well as the capability for precise air launched missile programming. These advanced radar modes will also permit accurate position updates to be accomplished at much greater ranges than with conventional radar systems. Accurate position updates will be limited only by the radar line-of-sight and will enhance the stand-off capability and permit greater flexibility for target aiming point selection.

Advanced radar design will be affected by both the natural and artificially induced environment. A hostile enemy environment will place many demands on the radar system that could not be handled with a conventional radar. The flexibility and inherent capabilities of advanced radar systems will permit a realtime analysis of the electromagnetic environment to be accomplished and to initiate the appropriate response. The radar will be required to not only counter active jamming and interference techniques specifically directed toward the aircraft but also analyze the environment and to avoid detection from ever taking place. The inherent characteristic of microwave energy to penetrate weather has long provided aircraft with all weather, day/night operating capability. However, advanced radar systems must also permit penetration of ground foliage. Built-in flexibility will permit advanced radar systems to keep pace with the continuously changing environment of the future.

It is readily apparent, for advanced weapon systems in general, that crew member task loading is of vital concern due to both the complexity of the equipment and the ever increasing number of tasks that the crew member is called upon to do. (2) As a result, the design goal of all advanced radar systems will be to simplify the basic operation and to provide assistance to the crew member. In general, the operation of advanced radar systems will be simplified by virtue of the programmable capabilities of both the navigation computer system and the radar digital signal processor. A terrain following mode when tied into the aircraft flight control and navigation computer systems is one existing way of assisting the pilot. An example for future radar systems will be automatic target acquisition and classification modes for both air-to-ground strikes against both stationary and moving targets, and air-to-air modes for enemy aircraft interception. The inherent high resolution characteristics of synthetic aperature radar (SAR) and doppler beam sharpening (DBS) modes when integrated with the accuracy of navigation and weapon delivery computers also reduces the crew members task load by providing an automatic means of accurately classifying a target or aiming point. This capability is essential in single seat fighter aircraft where the workload is high or in any high speed aircraft operating at low altitudes where the limited radar range results in a short time for the crew member to react to a target.

In summary, the role played by advanced radar systems will continue to include the traditional tasks of general navigation and weapon delivery. However, many enhancements to the basic capabilities and the addition of new specialized modes will permit advanced radar systems to meet the requirements for a high performance sensor capable of operating in a wide variety of environments and capable of reducing the crew member's workload.

DRLMS Requirements for Advanced Radar Systems

The requirements for the simulation of advanced radar systems will be based primarily upon current DRLMS specifications. Although current specifications have evolved since the first DRLMS specification in 1972, experience gained in more recent years, as well as the more demanding requirements of future radar systems, dictates that a number of significant modifications be made. (3)

From the standpoint of the actual radar system being simulated, the most obvious types of changes to current simulator specifications will be the inclusion of the new types of modes and requirements for any system unique characteristics. Characteristics that may be required include such items as the effects of radar platform motion compensation or digital signal processing anomolies on the resulting radar imagery. Analysis of a specific radar system's operation will dictate which unique system requirements will be required. A requirements emphasis will be placed on a DRLMS design approach that will permit expansion when additional modes and capabilities are added to the aircraft radar system. It becomes highly undesirable for a DRLMS system to require a total redesign or possibly have to be replaced if the existing aircraft radar is modified with the addition of a new mode or capability.

Requirements changes that will most likely affect DRLMS processing capability include accuracy and data density. In both cases, an attempt will be made to further definitize and more quantitatively specify the level of performance required. DRLMS accuracy (processing and data transformation) will continue to be specified independently for both terrain elevation and planimetry, as well as independently for each mode of operation. Of great significance, however, will be tighter planimetry positional accuracy requirements for the high resolution modes. Data density processing requirements will need to be modified to consider both real beam conventional modes and synthetic aperature high resolution modes. Conventional real beam mode density requirements will remain relatively stable; however, the high resolution data density processing requirements can be expected to become more stringent. However, when considering both accuracy and density processing requirements, several important factors must be kept in mind. First, data processing times for individual radar frames on actual aircraft SAR modes are typically several seconds long with an update rate that may be even longer. Second, the individual frame location will most likely be fixed without the need to process data in real time as cross hairs are slewed virtually anywhere within the aircraft field of view. Also of concern when considering DRLMS processing capability is the extent to which world wide flight will be required. Recent programs have emphasized the need for mission rehearsal encompassing potentially the entire northern hemisphere. This requirement will have to be reevaluated in terms of training utility and effectiveness - especially when reviewed in light of DRLMS design complexity and demands that will be placed on high resolution data bases.

A goal for future DRLMS specifications will be the addition of as many quantitative requirements in place of areas that are now subjectively defined. This will be especially true in the areas of radar effects and special effects where words as "shall be realistically simulated" predominate. It is also important to note that quantitative requirements will be based upon training effectiveness studies whenever possible. Since it is realized that quantitative performance characteristics can tend to drive both design and production costs of DRLMS, careful attention will be paid to the desired fidelity as a function of training requirements.

The DMA digital landmass system (DLMS) data base has been the primary source of data for the simulation of conventional ground mapping radar systems over the last ten years. (4) However, the DLMS data base possesses certain limitations that will influence both the requirements for DRLMS data bases and the eventual design of advanced DRLMS systems. These limitations are centered around the basic content of DLMS data. DLMS digital feature analysis data (DFAD) is produced to a set of resolution and feature type inclusion criteria which results in a chart like representation of the earth's surface where homogeneous type areas (e.g. soil, trees, desert, water, etc.) are represented; however, a more precise description of how soil is contoured or plowed, or how trees and foliage are distributed in natural vegetation areas is not contained. As a result, Level 1 DFAD, and to a lesser degree Level 2, will be inadequate for meeting the data content requirements for a high resolution SAR mode. As indicated in a prior discussion, areas of high resolution interest for a simulator training mission will be restricted to relatively small areas selected during mission generation. Various methods will, therefore, have to be developed to either enhance the basic DMA data in these areas or to provide an alternate data source for the high resolution modes. One alternative currently under evaluation is the use of synthetically enhanced DMA data. (5) Synthetic breakup is an automated process of replacing large homogeneous DFAD features with smaller, more realistically sized, individual features. (Figure 1) Although very encouraging results have so far been obtained, certain limitations do exist. The data, when broken up, is random in nature and not necessarily representative of what actually exists in the real world. This is a result of the limited number of descriptors assigned to an individual DMA feature (e.g. feature type, surface material, predominant height, etc.). For example, for a residential area digitized as a single feature, the feature descriptors will not provide any indication of what variations to the basic feature type exist in the real world or if there are any unique characteristics. The capability to generate more realistic synthetic breakup should be realized when more descriptive data bases, such as DMAs experimental Level V, becomes an available product. Other alternatives to the need for a more detailed data base are the inclusion of generic models (i.e. small areas hand modeled to the level of desired feature content and fidelity) into areas of high resolution interest and, to go a step further, generate a complete generic data base. Such a generic data base might be based upon the DMA data base (e.g. Level 1, 2, or V) on which extensive synthetic enhancement and generic modeling is added or might be entirely artificial in content - realistic in appearance but not representing any real world area - but tailored to meet a specific training need. In any case, more detailed data bases are the primary reason why data density processing requirements will be higher for the simulation of high resolution radar systems.

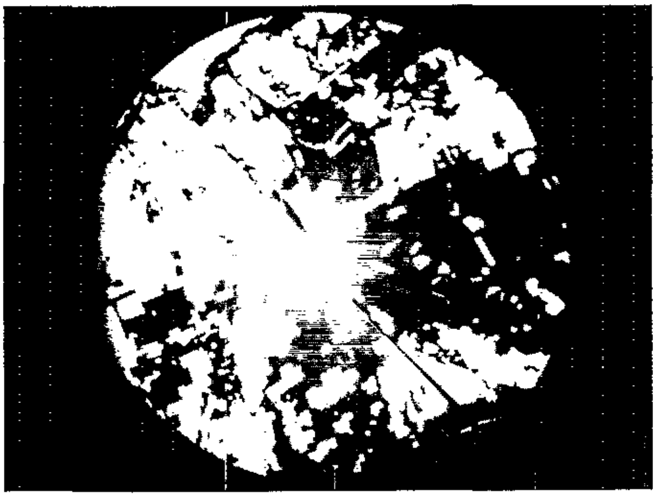
Although not directly related to the requirements for advanced high resolution radar simulation, DRLMS test requirements will also undergo extensive modifications. For the most part, current test requirements are general in nature and a great deal of interpretation is left to the DRLMS system designer. As part of the same effort to quantify the requirements for DRLMS fidelity and processing, DRLMS test requirements will also become more quantitative and more definitive as to how they are to be performed. The goal will be to reduce the subjectivity of DRLMS testing and to achieve the most quantifiable picture of system performance as possible.

In summary, modifications and additions to DRLMS specifications for advanced DRLMS systems as described in the preceding paragraphs are "a goal" to be accomplished in various states during the next five to eight years. It is hoped that certain quantitative performance and test requirements can be added in the next two to three years. However, advanced radar system unique requirements will not be available until an advanced aircraft radar system is fully defined.

DRLMS System Design Impact

One can only speculate as to the total impact advanced radar systems will have on DRLMS design. After looking at the anticipated changes to DRLMS specifications, however, it does appear that the two primary areas of concern for advanced DRLMS will be the data processing capability (i.e. data volume and processing speed) and data base adequacy. It can be anticipated that for conventional ground mapping radar modes, current DRLMS technology will suffice. Current DRLMS technology may also serve as an interim in the near future for high resolution modes; however, several enhancements and several alternatives can be considered.

As discussed in the previous section, synthetic breakup, when fully exploited, is one way of enhancing the data base. One alternative to breaking up the source DMA data base would be to accomplish the breakup of cultural features during realtime processing thereby reducing the amount of on-line storage and data base transformation time. However, careful attention would have to be given to the capability of generating a desired pattern of artificial features and do so in a repeatable manner from scan to scan. Similar to the concept of synthetic breakup would be the realtime generation of texture to be applied to terrain and agricultural areas. Texture patterns should also be selectable and repeatable but would probably be less critical than for cultural features. Generic modeling might also be a means of providing the high data content and detail necessary for high



BEFORE BREAKUP

AFTER BREAKUP

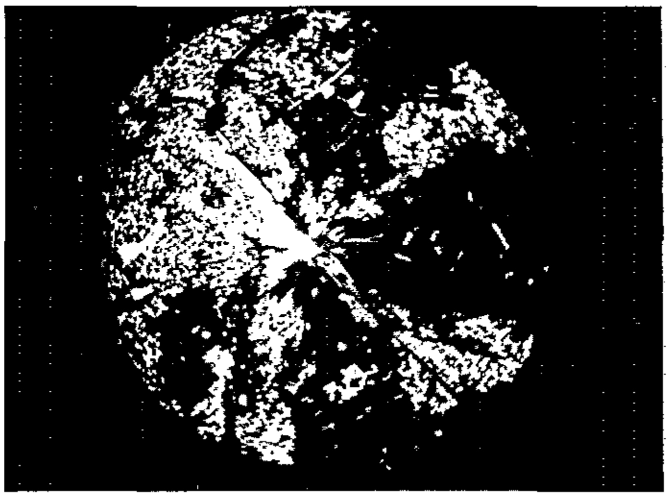


Figure 1. Synthetic Breakup of DMA Data

resolution modes. Generic models of small towns, industrial complexes, residential areas, etc, could be hand modeled as part of a generic library collection to be inserted in the data base either before transformation or during realtime DRLMS processing.

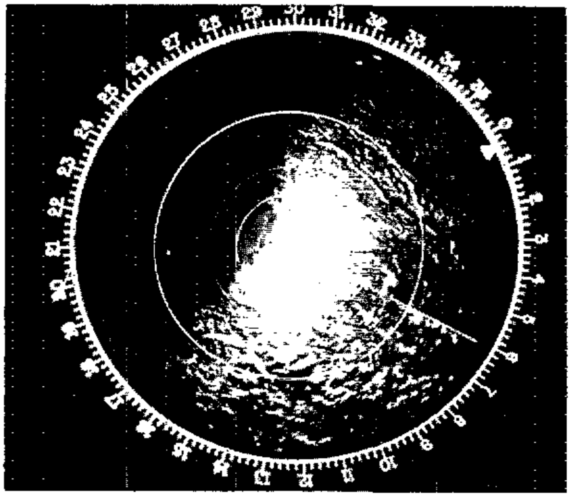
It appears that current DRLMS technology will be adequate for conventional ground mapping radar modes. Figure 2 illustrates a comparison between simulated and actual B-52 radar imagery. In order to accomplish data retrieval and processing for advanced high resolution radar modes, however, either a higher performance DRLMS processor (parallel to the conventional ground mapping channel) or an alternative high fidelity image generation capability would be required. This would then imply that hybrid DRLMS systems may be a solution for the simulation of advanced multi-mode radar systems. Computer image generation (CIG) techniques, used for out-the-window visual simulation, might be explored. This possibility is appealing from the standpoint that high resolution SAR modes are capable of producing imagery that in many cases contains the same detail and resolution as a visual scene. (Figure 3) In addition, high resolution modes typically utilize digital scan converted video which is output to a raster scan type display. This display format is also utilized for CIG image display.

An alternative to be considered from both a data base and processing standpoint is realtime processing of an array of still photographs. (6) This process, successfully demonstrated for the simulation of airborne forward looking infrared (FLIR) systems, also seems to hold possibilities for high resolution radar modes. High resolution aircraft radar imagery (e.g. synthetic aperture) doppler beam sharpening, side looking, etc.) could be processed in a similar manner as that for a forward looking infrared or visual system, thereby providing a simulation capability with virtually the same level of fidelity as the original aircraft imagery. However, a significant amount of effort would have to be devoted to the questions of dynamic shadow processing, dynamic system controls interaction by an operator, and the processing of radar data base photography at very low grazing angles (i.e. low altitudes and long ranges).

In order to accommodate future growth of DRLMS systems as a result of aircraft radar system modifications, DRLMS system architecture will need to be designed with an understanding of what potential changes may exist in the future. Although it is certainly naive to think that all contingencies can be "designed in" thereby eliminating the chance of DRLMS system redesign, good design planning should help to increase the chances of a more graceful transition to the new capabilities. For example, if additional processing power is required, what level of effort would be required to expand with a parallel processor or, if additional data storage is required, what level of effort would be required to add additional memory? Similar type questions should be asked of the basic radar effects. If aircraft radar performance is increased, how easily can the antenna beam pattern or receiver effects be modified? Just as modern digital radar systems provide growth capability to aircraft radar systems, it is hoped that modern DRLMS systems will also inherit this flexibility.

SUMMARY

During the next ten years, we will see a quantum jump in the performance of airborne radar systems as compared with the last forty years. As a result, innovative new ideas will be required to advance the state-of-the-art in DRLMS system technology in order to meet the performance requirements for advanced radar simulation training needs. It now appears that either significant improvements to existing DRLMS technology or alternative approaches resulting in hybrid systems will be required as well as a substantial increase to the content and detail of the radar data base. Just as a technical challenge existed in the 1970's to develop digital radar simulation technology to meet the training needs for conventional radar systems, an even greater challenge now exists to meet the training requirements expected for the advanced high resolution radar systems of the 1980's and beyond.



ACTUAL
RADAR
IMAGE

SIMULATED
RADAR
IMAGE

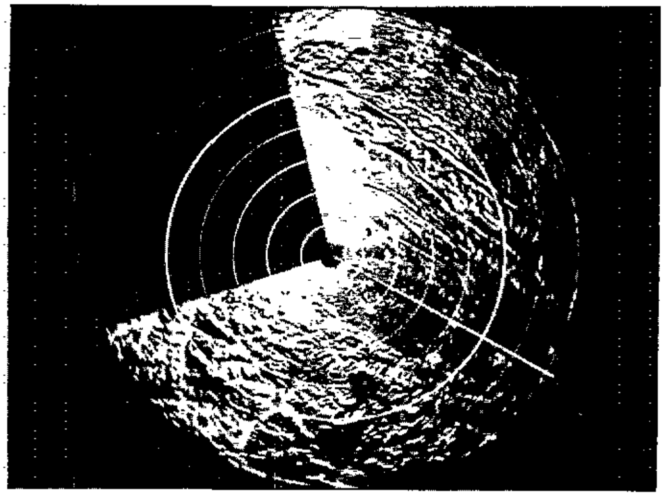
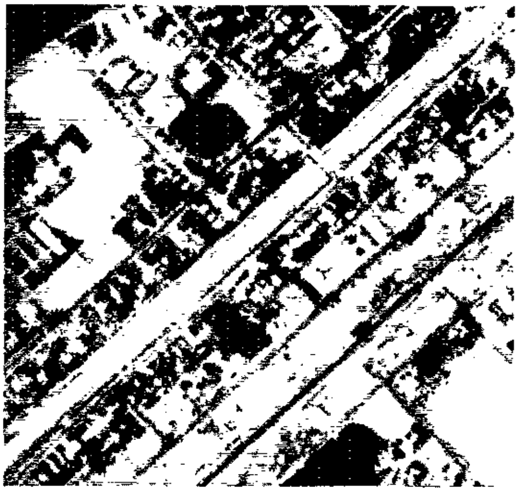


Figure 2. Simulated vs. Actual Radar Imagery



AERIAL
PHOTOGRAPH

SYNTHETIC
APERTURE
RADAR IMAGE

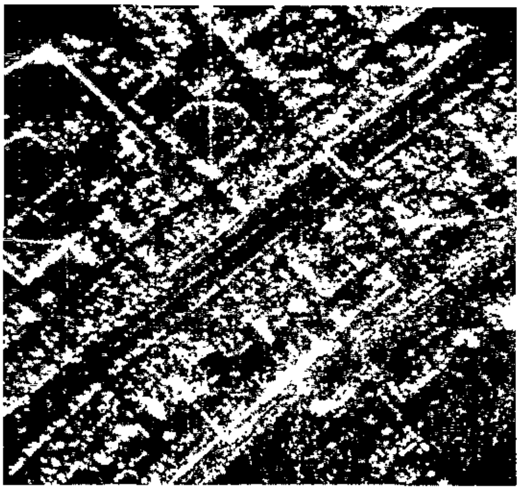


Figure 3. Synthetic Aperture Radar Image

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ABOUT THE AUTHOR

Mr John D. Stengel, Jr. is a DRLMS and digital data base systems engineer, within the Aeronautical Systems Division's Visual and Electro-Optical Branch, Deputy for Engineering at Wright-Patterson Air Force Base, Ohio, (ASD/ENETV).