AIM-120A DOPPLER RADAR TELEMETRY DATA REDUCTION AND ANALYSIS SOFTWARE

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ABSTRACT

This paper describes the application software used to convert AIM-120A, Advanced Medium Range Air-to-Air Missile (AMRAAM), telemetry data to a series of color images and time-correlated engineering unit results. X Window System-based graphics facilitate visualization of the doppler radar data. These software programs were developed for the VAX/VMS and DEC Alpha environments.

KEYWORDS

AIM-120A, doppler radar, X-Window System.

INTRODUCTION

The AIM-120A is an all-weather, beyond-visual-range missile employing an active pulse doppler radar system that processes both range (time) and doppler (frequency) information. The pulse doppler radar uses a Fast Fourier Transform (FFT) in the post detection processing loop to lower detection thresholds and increase detection probability. The purpose of this paper is to describe a software application series developed for the extraction, engineering unit conversion, display and analysis of AIM-120A, Advanced Medium Range Air-to-Air Missile (AMRAAM) telemetry data.

The AMRAAM telemetry is interrupt-driven—data output is determined and controlled by the phase of the missile's flight. This approach supports sub- and supercommutation of variables when sampling requirements necessitate data

collection at rates above or below the overall telemetry frequency; however, the burden imposed by this requirement sacrifices some of the original data event sequence. For this reason, the data are grouped into blocks and each block is time stamped with the missile's flight time to allow for reconstruction of flight chronology.

The objective of processing performed on the missile telemetry is to identify, correlate, and extract information that can be used to evaluate FFT processing using color representations of the filter processor data. Prior to the availability of methods for color image presentation of range/doppler radar data, FFT analyses were accomplished by reviewing computer printouts where the numbers represented the measured power level in each range/doppler frequency bin. The number of bins was equal to the number of range gates times the number of doppler filters. This data was provided to analysts in snapshot intervals at the FFT output rates. While this method did provide useful insights, it was difficult to recognize subtle changes in the radar environment such as those changes associated with responsive electronic countermeasure (ECM) techniques.

TELEMETRY PROCESSING BACKGROUND

Due to the complex structure of the missile telemetry and the in-depth analysis requirements for each flight test, a stepwise data processing approach was used. The engineers needed to analyze actual radar signal returns, post-detection processing results, and other system parameters. For analyzing any single detection event, the parameters are scattered about in different locations within a telemetry frame, requiring multiple frames to capture all relevant parameter results. The stepwise data extraction approach allowed the software to be broken into manageable, easily recognizable pieces, providing a more flexible and maintainable product that can interface with other software.

FILTER PROCESSOR DATA EXTRACTION

The first cycle of processing performed on telemetry is to identify and extract the filter processor signal amplitudes. Each major telemetry frame has an associated IRIG-B time tag defined as the millisecond time associated with the first word after the major frame synchronization pattern. The amplitudes are placed into the telemetry in blocks of data words, and each block has an associated missile clock time stamp and block ID number. The missile clock time stamp is taken directly from each filter processor data block, and it uniquely identifies the range/doppler matrix for this data block. The block number indicates the position for this set of data words in the matrix. Multiple data blocks having identical time stamps and unique block numbers are required to reconstruct a single range/doppler matrix; however, because the AIM-120A telemetry

is interrupt-driven, the data blocks for a complete matrix are intermingled with blocks from the previous and subsequent matrices. The filter processor extraction program locates the data blocks needed to construct a single range/doppler matrix, determines when an entire set has been located and outputs the complete range/doppler matrix, missile clock time stamp, and IRIG-B time tag. This program also deals with telemetry noise and/or data dropouts that can impact program function. Incomplete or partial matrices which can occur because telemetry dropouts are included in the output. This "missing data" is marked by the use of a semaphore value for quick recognition in subsequent processing steps. Finally, the telemetry major frame number and data file record number are included with the filter processor data in the output.

PARAMETER CORRELATION AND EXTRACTION

The second processing step is controlled by the missile clock time stamp written during the filter processor data extraction. The purpose of this step is to obtain engineering unit results relevant to the range/doppler radar analysis. To facilitate the correlation of other telemetry data with filter processor results, all other data uses the same data block time concept described for filter data blocks. Each data block begins with a missile clock time stamp. This time stamp is used to drive the time correlation, data extraction, and engineering unit conversion of 50 autoselected and up to 128 user-selected telemetry variables. The autoselected variables are used to control different display techniques. The remaining 128 variables are selected by the user to satisfy analysis requirements.

The time correlation of the telemetry variables is satisfied by using the missile clock time stamp, telemetry frame number and data file record number to establish an upper and lower limit on the telemetry frames to be searched for "best" time correlation. "Best" is defined as when a filter processor data block time stamp is greater than or equal to current range/doppler matrix time stamp but not crossing over into the interval covered by next sequential matrix time stamp. The total number of telemetry frames searched to locate "best" results can cover up to 12 major frames (particularly when trying to locate subcommutated variables).

Once the correct telemetry time frame is located, the autoselected, user-selected, and associated dependent variables are extracted from the telemetry. The autoselected variables are part of the missile telemetry and are used to control aspects of the extraction process determined by the missile flight phase or missile configuration. User-selected variables are chosen by the engineer based on analysis requirements and can be any of up to 4000 telemetry variables. A dependent variable is one whose value at any specific point determines the validity of another variable.

In this application dependent variables are used to ensure correct extraction of an autoselected or user-selected variable. Each selected variable becomes the head of a linked list of variables with the tail of the list being the most subordinate dependent variable. Each variable in the list, with the exception of the most subordinate dependent variable, is dependent upon some other variable or variables being equal to a specific value or range of values. On the average, a single variable's link list has two to five variable dependencies.

At this point in the processing, the extracted value for individual variables is in raw format. In this format a variable is defined by its telemetry location or start word, field length, scale factor, displacement, time offset and other relevant extraction details determined by a telemetry data dictionary. The conversion of the raw data to engineering units proceeds starting at the tail end of each variable's linked list. The raw data result for each variable in the list is converted to engineering units and its value is tested for validity. At the first occurrence of a result that does not satisfy the variable's condition test, the remainder of this variable's linked list is abandoned and the selected variable is not updated. For this reason, up to 12 telemetry frames are searched in an attempt to ensure all user-selected variables update at every possible opportunity.

Specific variables can be updated, carried forward, or zeroed. A variable is updated when a new result satisfying all dependent conditions is extracted from the telemetry. A variable is zeroed when three consecutive filter processor matrices (approximately 10 telemetry frames) have failed to yield a new result. In this case, the affected variable is considered to have "aged out" and is zeroed to flag it. Ageout can occur for either a change in missile flight phase where specific variables no longer have meaning, or due to telemetry dropouts. Subcommutated variables are the exception to the ageout criteria. These variables are updated at every opportunity, but when a new result is not available, the most current value is carried forward.

COLOR IMAGE GENERATION

The third and final processing step is the conversion of the filter processor data matrices to color bit-mapped images. The set of autoselected variables extracted in the previous step contains several variables that identify the current range gate and doppler filter configuration being used by the missile. It is the missile configuration and specific range gate that determines the algorithm used for transforming the raw signal amplitudes into color table indexes. Color indexes are in the range of 0-248 where index 0 is red, 124 is yellow, and 248 is blue, with indexes between these defined as intermediate colors (e.g., indexes 2 through 123 start with shades of red progressing to orange and then to yellow). The same set of 249 colors is applied using

one of two basic algorithms. Some gates are transformed using a linear scale, others using a logarithmic scale. The specific algorithm is dependent upon the range gate in which the amplitudes occur and the current missile range gate configuration (Table 1).

One special data condition, "missing data," is handled in this processing step. This condition occurs when a partial matrix has been written during the filter processor extraction because of telemetry dropout. In this situation, the "missing data" block is flagged using the color table index that equates to white for easy recognition.

Table 1. Filter Amplitudes to Color Transformation

Range Gate	Counts	Transformation	Colors	# Colors
Δ	greater than +500	none	blue	1
	less than -500	none	red	1
	$-500 \leq$ counts $\leq +500$	linear	red-yellow-blue spectrum	249
Δ or Σ	"missing data" = -32767	none	white	1
Σ	greater than +10000	none	blue	1
	less than 0	none	red	1
	$0 \leq$ counts $\leq +10000$	natural log	red-yellow-blue spectrum	249

RANGE/DOPPLER MATRIX ANALYSIS

The ultimate goal of the telemetry processing described to this point is to analyze range/doppler radar performance. The Range/Doppler Matrix (RDM) Analysis program enables the analyst to visualize the radar returns in terms of the radio frequency environment in which the radar operates. Although this program cannot provide all the answers needed by the analyst, it does give a one-of-a-kind look into AIM-120 pulse doppler radar performance. This is an X Window System-based application using Motif/DECwindows and DECwindows FORTRAN language bindings. User-selected engineering unit results and color images can be displayed and manipulated via this application.

At program startup, the user is placed in a menu-driven windowed interface whose major components are the status window, image display, parameter display, and command menu (Figure 1). The status window that runs across the top provides the current range/doppler matrix IRIG-B time stamp, missile clock time stamp, matrix frame number, and current values for key missile parameters. The image display window is used to present the range/doppler matrix images. Initially, the matrices are

Range/Doppler Matrix Analysis (V2R1)

12:00:0.192/ 0.257   Frame: 17   MPHASE=0   NTGT=0   SBMOUT=3402   FAZEL=0   Config:5/5

G1340E01
DEFAULT 128

FORMAT
2D | 3D | Dual

MODE
Single Frame
Five Frame
Full Flight

MAGNIFY
2X | 3X | 8X
User Zoom

MOTION
Forward Frm
Backward Frm

RNG GATES
Reverse
Waterfall
Single Gate
Time History

EXAMINE
Amplitude
Highlight
Detections

PRINT
Counts/Tele.
B/W Waterfall
Color Image

SELECT
TM File
Extraction

EXIT RDM

Max

Min
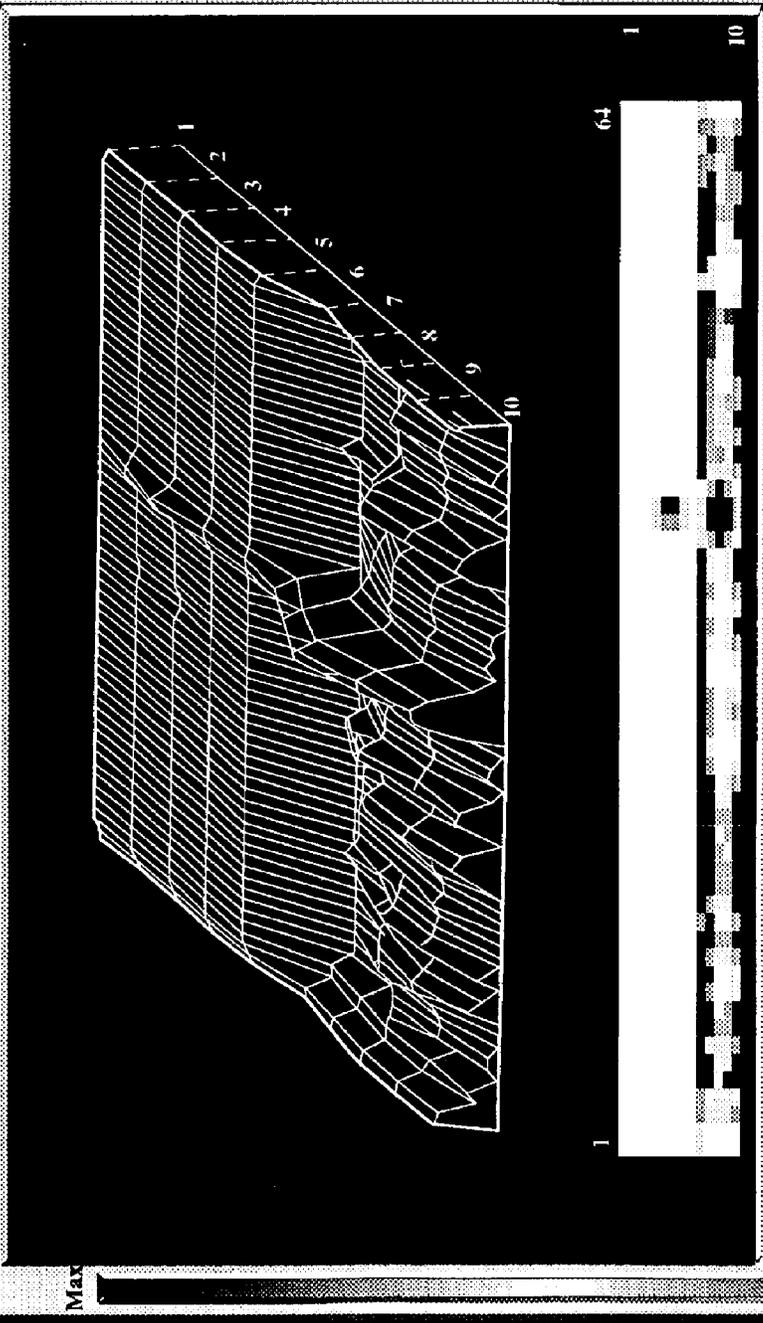
10596.403-TOP91	11214.613-TOP92	6901.766-TOP93	9801.098-TOP04
2553.084-TOP09	6783.477-TOP10	127.185-TOP11	6842.624-TOP12
4722.452-TM01	4293.266-TM02	2645.949-TM03	1210.234-TM04
11703.942-TM09	2132.187-TM10	9770.134-TM11	2883.277-TM12
67103-TM17	40330-TM18	39412-TM19	51700-TM20
67322-TM25	7540-TM26	4516-TM27	32566-TM28
18873-TM33	88548-TM34	5740-TM35	29226-TM36
6519-TM41	28151-TM42	6922-TM43	26393-TM44
11902.189-TM49	3575.828-TM50	5192.063-TM51	7998.684-TM52
2564.865-TM57	5716.660-TM58	7070.213-TM59	2420.559-TM60
4159.648-TM65	8312.297-TM66	2309.941-TM67	3163.801-TM68
4311.433-TM73	10516.517-TM74	11993.553-TM75	5300.204-TM76
61993-TM81	67071-TM82	70880-TM83	67134-TM84
54915-TM89	20493-TM90	51978-TM91	86979-TM92
81122-TM97	41680-TM98	21613-TM99	78650-TM100
39949-TM105	72912-TM106	92575-TM107	49570-TM108

K2:Pg B3:End

32:Pg B3:End

*

displayed in time sequence for the entire missile flight or to the limits of the display. Approximately 25 seconds of sequenced missile flight time can be displayed at one time; for longer flights, the image window scrolls to view the entire flight. The user is able to select among different display formats (2D, 3D, or Dual) and different display modes (Single Frame, Five Frame, or Full Flight). The 2D or two dimensional image presentation illustrates the layout of a single range/doppler matrix which is doppler filters across and range gates vertically. This is the most commonly used display format, but a 3D image display can be generated using the magnitude of the individual signal amplitudes or counts to construct the third dimension. The user can even display both the 2D and 3D formats simultaneously as seen in Figure 1. Furthermore, the 2D images can be displayed solo or in a five matrix sequence and the user can move through the images either forward or backward. Finally, the user can select special purpose display formats such as single range gate display or scrolling range gate time history when the need arises. The parameter display window is used to present the time correlated, engineering unit telemetry results or raw signal amplitudes used to create the color images displayed in the image window. Lastly, the command menu contains the function buttons used to control the various presentations.

The command menu is the principal user interface to the extracted data. Active functions are indicated by a yellow function button title, and inactive actions are de-emphasized using gray function button titles. The specific functions active at any point in time are dependent upon the current display mode and format (Table 2). Functions have been added to allow reselection of telemetry extraction data files, generate numeric print files of telemetry results, and black/white or color image hardcopy. In addition to the different image presentations, the analyst can use specific mouse buttons within certain windows to invoke accessory display information. This accessory information includes readouts of individual matrix signal amplitudes, telemetry variable units, telemetry variable highlighting, target detection results, or amplitude threshold crossings. The mouse buttons can be used to control frame-by-frame presentations where one button moves forward or backward through single frames, and another button provides continuous forward or backward motion control while the button is depressed.

Table 2. RDM Command Function Summary

Function	Button	Button Description	When Active
FORMAT	2D	two-dimensional matrix display	selected modes
	3D	three-dimensional matrix display	
	Dual	both 2D and 3D matrix displays	
MODE	Single Frame	single matrix display	any format
	Five Frame	five matrix sequence display	
	Full Flight	entire flight sequence display	
MAGNIFY	2x	2x magnification	full flight mode
	4x	4x magnification	
	8x	8x magnification	
	User Zoom	user selectable magnification	any mode
MOTION		matrix animation on/off	any format/mode
	Forward Frm	advances to next matrix	
	Backward Frm	decrements to previous matrix	
	MB1: single matrix motion MB3: continuous motion while depressed		
RNG GATES	Reverse	reverses gate order top to bottom or front to back	any single matrix mode format
	Waterfall/Spectral	wireframe 3D matrix or colorized based on filter amplitude	
	Single Gate/ All Gates	examine any individual range gate	
	Time History/ History Off	examine any individual range gate in time sequence left to right	
EXAMINE		activates detection/threshold overlay	2D or dual format single matrix mode
	Amplitude/ Telemetry	switches between filter amplitude and user-selected telemetry results	any format/ mode
	Highlight/ No Highlight	deactivates telemetry result highlighting	
	Detections/ No Detections	activates scrolling detection windows	2D format single matrix mode
PRINT	Counts/Tele	generates print files of current telemetry results and filter amplitudes	any format/mode
	B/W Waterfall	black/white	3D format single matrix mode
	Color Image	generates color print file of image window contents	any format/mode
SELECT	TM File	reselection of current telemetry results file	any format/mode
	Extraction	background extraction of up to 16 "got to have" telemetry variables	
EXIT RDM		deinstall RDM colormap and exit	any format/mode

CONCLUSIONS

This series of programs was developed for the Air Force Development Test Center (AFDTC) at Eglin AFB Florida, and is hosted on a DEC VAX/VMS or DEC Alpha/OpenVMS workstation. This software was initially released in May 1992 with several updated releases since that date. The success of this software is the result of daily interaction between the AIM-120 analysts and software engineers. The improvement of this software to provide greater access to missile telemetry data continues. Software development efforts are underway for a UNIX-based version of this AIM-120 software and extension of the RDM program to support visualization of telemetry from other doppler radar systems.

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