Target Detection and Offline analysis of RADAR data from

MIL-STD-1553B

N.K.SRINATH
Professor
Dept. Of ISE,
R.V.College of Engg.,
Bangalore, INDIA
E-mail:
srinath_nk@yahoo.com

Dr.RAMAKANTHKUMAR.P
Professor
Dept.of CSE, R.V.College of
Engg., Bangalore, INDIA
E-mail:
pramakanth_2000@yahoo.com

G.PRABHUSHANKAR
TOA' Centre for Airborne
Systems, DRDO Yemlur
Post,Bangalore-37
INDIA
Email:
g_prabhu33@yahoo.com

Abstract: - The proposed system entitled "Target Detection and Offline analysis of RADAR data from MIL-STD-1553B" will detect the target, plots the position on the screen and help the pilots, test engineers and RADAR evaluation team during offline. The path of the TARGET and HOST/HACK aircrafts are analyzed along with navigation specific parameters. The system has the mechanism to save the HOST/HACK and TARGET information during flight. The system will also work in on-line mode. During the on-line mode the TARGET information is detected by the RADAR and is available on MIL-STD-1553B Bus. Using the Bus Monitor (BM) mode the relevant data is extracted. Using this data the flight position of the TARGET aircrafts are calculated. In off-line the recorded data's are used to calculate the positions of the aircrafts and the paths of the aircrafts. It is plotted on the map in a graphical window. All the navigation details of the aircraft are displayed on a tote window for RADAR data analysis purpose.

Key-Words: - RADAR, MIL-STD-1553B, UHF, TDMA, TARGET

1 Introduction

Radar data is used for various applications. One of them is for aircraft and flight control [1-2]. The antenna design and type is a factor that affects the data capture in an aircraft [3]. During the flight in on-line mode, the RADAR data is available on the MIL-STD-1553B bus. The MIL-STD-1553 networking technology is extensively used in a number of military and aerospace platforms including applications on aircraft, ships, tanks, missiles, satellites, and even the International Space Station [4]. The clutters, noise, and other factors may affect the data captured [5]. MIL-STD-1553 bus, monitors for data in Bus Monitor mode and stores it in the file for offline analysis. In offline analysis mode, the RADAR file is parsed for valid messages. The extracted data is stored in a file. The required parameters such as longitude, latitude, speed and altitude are obtained from the extracted data.

This paper is organized as follows: The system architecture is provided in Section 2. Section 3 provides the system implementation. Section 4, concludes describing the results; Section 5 concludes the references.

2 System Architecture

An antenna is a device that transmits and/or receives electromagnetic waves. A feeder supplies the power for this, which is often a length of transmission line or waveguide having well-defined characteristic impedance. One can regard an antenna as a kind of transducer to turn generated electrical energy into radiating energy. An antenna must be tuned to the same frequency band [6] that of the radio system to which it is connected operates; otherwise reception and/or transmission will be impaired. There are several basic properties [7] that are common to all antennas: They are reciprocity, polarization, wavelength, aperture, directivity and gain, radiation patterns, near and far field, input impedance, beam width, bandwidth, azimuth elevation etc.
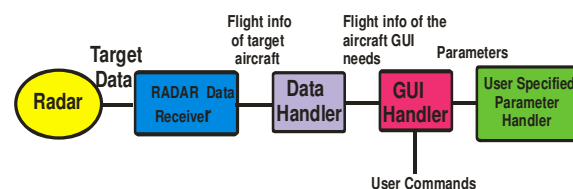

Fig. 2.1 Structure chart

This system is divided into five major modules, which are further subdivided into sub modules. The various modules are

> Radar Unit
> Radar Data Receiver
> Data Handler
> GUI Handler
> User Specified Parameter Handler

2.1 Radar Unit

A transmitter emits electromagnetic radio waves, which are reflected by the target and detected by a receiver, typically in the same location as the transmitter.

2.2 Radar Data retriever

It directly inputs data from radar unit. It acts as the interface between the system and radar receiver. Data is retrieved character by character and passed onto the MIL-STD-1533B data bus.

2.2.1 MIL-STD-1553B data bus.

Multiple Data Bus Protocol (MDPC) is an interface card to PC 16 bits EISA bus to MIL-STD-1553B avionics data bus [8]. MIL-STD-1553B operates as Bus Controller, Remote Terminal, Monitor Terminal and Monitor/RT.

2.2.1.1 Bus Controller

The bus controller is responsible for directing the flow of data on the MIL-STD-1553 data bus. While several terminals may be capable of performing as the bus controller, only one bus controller may be active at a time. The bus controller is the only one allowed to issue commands onto the data bus. The Bus Controller takes care of all message transaction initiations and termination. It controls the message handling through command block. The command block screen displays the bus controller executable structure – control work, command word1, command word2, data pointer, status word1, status word2, timer values and the branch address along with the data words associated with the current message.

2.2.1.2 Remote Terminals

Remote terminals are defined within the standard as "All terminals not operating as the bus controller or as a bus monitor". Therefore if it is not a controller, monitor, or the main bus or stub, it must be a remote terminal. The remote terminal comprises of the electronics necessary to transfer data between the data bus and the subsystem. For 1553 applications, the subsystem is the sender or user of the data being transferred. Remote terminals are like a slave of BC. RT descriptor is the heart of Remote terminal which consists of 512 byes of memory spaces. This has the information of the RT Descriptor block data structure.

2.2.1.3 Bus Monitor

A bus monitor is a terminal that monitors the exchange of information on the MIL-STD-1553 data bus. The standard strictly defines how bus monitors may be used, stating that the information obtained by a bus monitor be used "for off-line applications (e.g., flight test recording, maintenance recording or mission analysis) or to provide the back-up bus controller sufficient information to take over as the bus controller." A monitor may collect all the data from the bus or may collect selected data. The reason for restricting its use is that while a monitor may collect data, it deviates from the command-response protocol of the standard; in that case a monitor is a passive device that doesn't transmit a status word and therefore cannot report on the status of the information transferred. Bus Monitor mode has a lot of applications and is similar to BC command block. Here the user can select via the control register whether to monitor all the remote terminals or selected terminals as declared.

2.2.1.4 Monitor Terminal Hardware

The electronic hardware between a remote terminal, bus controller, and bus monitor doesn't differ much. Both the remote terminal and bus controller (and bus monitor if it is also a remote terminal) must have the transmitters/receivers and encoders/decoders to format and transfer data. The requirements upon the transceivers and the encoders/decoders don't vary between the hardware elements. Monitor/RT is for applications that require simultaneous Remote Terminal and Monitor Terminal operations.

The monitor terminal used is SμMMIT Monitor Terminal (SMT). It may be required to be the Backup Bus Controller (BBC). With this in mind, the SMT architecture is designed to function like the SBC's architecture. The SMT's architecture is based on a monitor block structure and internal, programmable registers.

Designed to run autonomously and reduce HOST overhead, the SMT automatically executes data handling, message error checking, memory control, and related protocol functions. Monitor features and functions are –

- Command History List
- Executable Architecture
- BIT Capability
- Interrupt History List
- Monitor All or Selected Terminals
- Memory Management

To initialize the SµMMIT as a monitor terminal, following registers needs to be updated. These registers offer many programmable functions and allow HOST access to extensive information. All register bits are active high and reflect logic zero condition (0000 hex) after Master Reset (except those reflecting input pins). Each register associated with the monitor mode of operation is described below.

Message Information Word

Bit Number	Description
15-12	Default. With the monitor block architecture resembling the SBC Command Block architecture, these bits default to a "0100" state (Which is the Execute and Continue opcode) in case the monitor must switch to the BC mode of operation.
11-10	Default. With the monitor block architecture resembling the SBC, these bits default to a "00" state. If the monitor must switch to the BC, the retries will be set at fur per message.
9	Channel A/B. This bit defines on which of the two buses the command was received. (Logic 1 = Bus A, Logic 0 = Bus B)
8	RT-RT Transfer. This bit defines whether or not the message associated with this monitor block was RT-RT transfer and whether the SMT saved the second command word. This bit will be set only if the SMT is instructed to monitor the Receive RT.
7-0	Message information. These bits define the conditions of the message received by the SMT for that particular monitor block. Each of the message information bits is defined in the following section.

Fig. 2. 2 Message Information Word

Message Information word
Command Word 1
Command Word 2
Data Pointer
Status Word 1
Status Word 2
Time - Tag
Unused

Figure 2.3 Monitor

| Reg. No.	Name	Address
0	Control Register	0000 (hex)
1	Operational Status Register	0001 (hex)
2	Current Command Block Register	0002 (hex)
3	Interrupt Mask Register	0003 (hex)
4	Pending Interrupt Register	0004 (hex)
5	Interrupt Log List Pointer Register	0005 (hex)
6	BIT Word Register	0006 (hex)
7	Time-Tag Register	0007 (hex)
8-10	Not Applicable	0008 to 000A (hex)
11	Initial Monitor Command Block Pointer Register	000B (hex)
12	Initial Monitor D.P. Register	000C (hex)
13	Monitor Block Counter Register	000D (hex)
14	Monitor Filter Register	000E (hex)
15	Monitor Filter Register	000F (hex)
16-31	Not Applicable	0010 to 001F
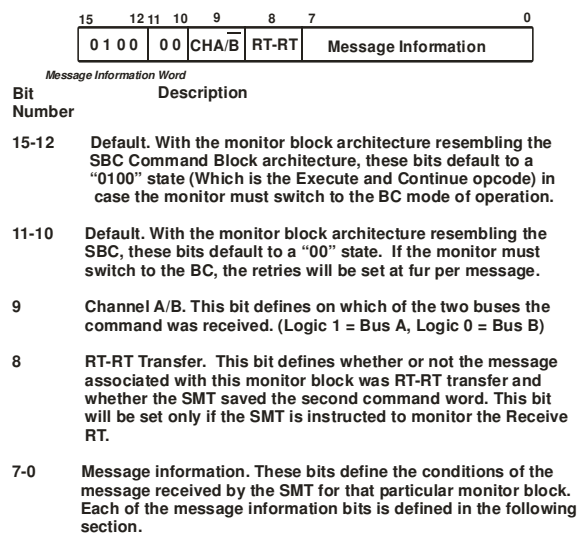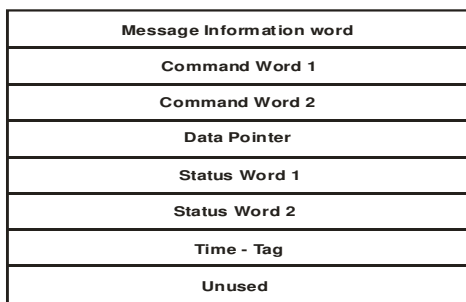
(MIL-STD-1553B Standard specifies a multiplex data bus for aerospace applications. This Standard defines requirements for digital, command/response, time division multiplexing techniques for I MHz serial data bus and specifies the data bus and its interface electronics. The characteristics of the data bus are given in the table-1. The primary purpose of the data bus is to move data between black boxes. How these boxes are connected and the methodology with which the communication is accomplished is central to the operation of the data bus. Multiplex data system techniques used in system integration promotes standard digital interfaces for associated subsystems to the data bus.
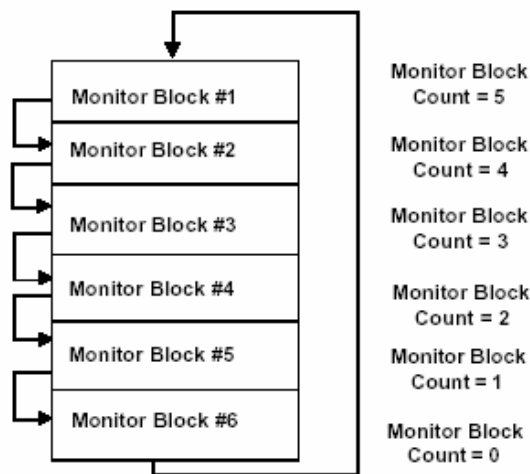

Figure 2.4 Monitor Block

Data Rate	1 MHz
Word Length	20 bits
Data Bits / Word	16 bits
Message Length	Maximum of 32 data words
Transmission Technique	Half-duplex
Operation	Asynchronous
Encoding	Manchester II bi-phase
Protocol	Command/response
Bus Control	Single or Multiple
Fault Tolerance	Typically Dual Redundant, second bus in "Hot Backup" status
Message Formats	Controller to terminal, terminal to controller, Terminal to terminal Broadcast System control
Number of Remote Terminals	Maximum of 31
Terminal Types	Remote terminal Bus controller Bus monitor
Transmission Media	Twisted shielded pair
Coupling	Transformer and direct

Table 2.1 Characteristics of MIS-STD-1553B bus

2.2.2 Sample Radar data
1. Time: Chronologic= 0 Milisec   Message
   Time: 0.088000 Milisec RADAR Bus-1 CMD
   f811 31-R-00-17 DATA 0007
2. Time: Chronologic= 1 Milisec   Message
   Time: 0.088000 Milisec RADAR Bus-1 CMD
   fba2 31-R-29-02 BC - RT DATA 0e10 1c06
3. Time: Chronologic= 1 Milisec   Message
   Time: 0.104000 Milisec RADAR Bus-1 CMD
   18b2 03-R-05-18   BC – RT DATA   0000
   0000 0000 0000 0000 0000 0000 0000 0000
   0000 0000 0000 0000 0000 0000 0000 0000
   0000 STATUS   1800
4. Time: Chronologic= 1 Milisec   Message
   Time: 0.360000 Milisec RADAR Bus-1 CMD
   1cc9 03-T-06-09   RT – BC STATUS   1800
   DATA   0001 0444 1000 0080 0ac6 0000 0722
   e561 0000
5. Time: Chronologic= 20 Milisec   Message
   Time: 0.216000 Milisec RADAR Bus-1 CMD
   f811 31-R-00-17 DATA 0001
6. Time: Chronologic= 21 Milisec   Message
   Time: 0.088000 Milisec RADAR Bus-1 CMD
   18b2 03-R-05-18   BC – RT DATA   0000
   0000 0000 0000 0000 0000 0000 0000 0000
   0000 0000 0000 0000 0000 0000 0000 0000
   0000 STATUS   1800
7. Time: Chronologic= 21 Milisec   Message
   Time: 0.360000 Milisec RADAR Bus-1 CMD
   4a10 09-R-16-16   BC – RT DATA   1e10
   1800 (TA)0000 0000 0000 0000 0000 0000
   0000 0000 0000 0000 0000 0000 0000 0000
   0000 0000 STATUS   4800
8. Time: Chronologic= 40 Milisec   Message
   Time: 0.360000 Milisec RADAR Bus-1 CMD
   f811 31-R-00-17 DATA 0002
9. Time: Chronologic= 41 Milisec   Message
   Time: 0.088000 Milisec RADAR Bus-1 CMD
   18b2 03-R-05-18   BC – RT DATA   0000
   0000 0000 0000 0000 0000 0000 0000 0000
   0000 0000 0000 0000 0000 0000 0000 0000
   0000 STATUS   1800
10. Time: Chronologic= 60 Milisec   Message
    Time: 0.360000 Milisec RADAR Bus-1 CMD
    f811 31-R-00-17 DATA 0003

2.3 Data Handler

It has two files for each Target Aircraft. First file stores the data send by the Target Aircraft itself and the second file holds the RADAR data for that Aircraft

The files are internally arranged in form of a queue with most recent entries added to the rear end. When flight information of an Aircraft has to be shown entries at the rear end is used and for mapping the flight path all entries are used. Old and outdated entries are removed from the front end.

The default settings for the user specified parameters and display modes are also stored here, which can be change by the user.
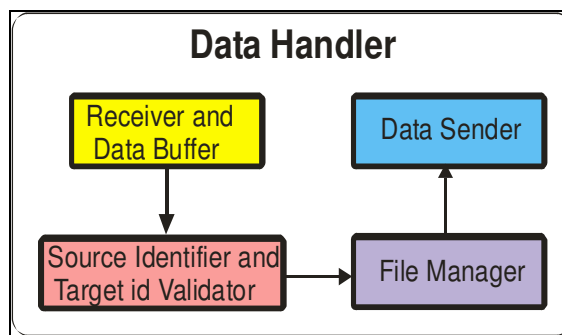

Figure 2.6 – Data Handler

2.3.1 Receiver and Data Buffer

It receives the data from each of the three data receivers modules and stores them in the buffer until all the data is received. When all the data has been received it is passed onto the Source Identifier and Validator.

2.3.2 Source Identifier and Validator

It identifies the source of the data which is a combination of the Target ID or HOST and the receiver from which it was received. Validity and integrity of the data is then checked. If the data is valid it is passed to the file manager.

2.3.3 File Manager

The basic function of this module is to provide functions through which new data can be stored in the appropriate files based of the source of data. Also old entries are removed automatically by the file manager, which are no longer required. Old entries are based on the number of entries in the file and this number can be defined by the user. It also provides interface to the default settings file, contents of which can be changed by the user.

2.3.4 Data Sender

This module sends the requested data to GUI Handler. It checks if the valid data exists for the Aircraft, which the GUI handler has requested for. It also checks if the request was valid or not.

2.4 GUI Handler

It handles the two display modes and user interaction. It retrieves flight information about the Target Aircrafts and the HOST Aircraft form the Data handler and using this it displays them on the map. When information about an aircraft has to be shown it displays the most recent entry from the Data Handler. When user wants to change some display parameters or he wants to change the display mode it passes the control to the Parameter Handler.

2.4.1 Command Interpreter

User interacts with the system using keyboard for giving commands. Command Interpreter checks the input string for a valid command and parameters (if any). If it's a valid command then the required action is taken. If the command is change mode then control is passed onto Mode switcher and if it is change parameter then control is passed onto Control Switcher. Other commands are also handled suitably.

2.4.2 Map Controller

The actions performed on the area where the map is displayed are termed as map actions. Some of the actions can be Zoom Out or Zoom In, click on a tote and change map. The map actions are taken care by this module. It gets flight information about Aircrafts through the Data Retriever to show them on the map and also extracts the map user wants in case of change map command.

2.4.3 Data Retriever

The basic function of this module is to retrieve flight information of a particular Aircraft from the Data Handler. Whenever Map Controller wants flight information it asks Data retriever to give data about a particular Aircraft.
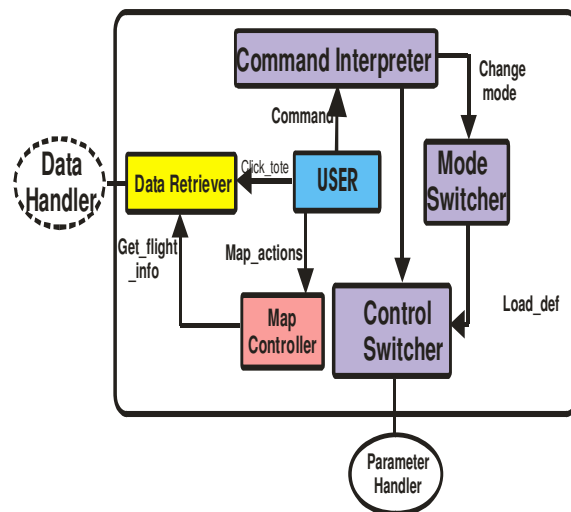

Figure 2.7 GUI Handler

2.4.4 Display Mode Switcher

When user wants to change the display mode, this module saves the current settings of the current mode, because these may be needed in future operation. It then passes the control to Control Switcher, so that default settings of the new display mode can be loaded.

2.4.5 Control Switcher

This module acts as an interface between the GUI Handler and the Parameter Handler. When user wants to change parameters control is given this module, which starts the Parameter Handler to load GUI handler again with changed parameters.

2.5 User Specified Parameter Changer

This is the module which is started at beginning. It handles the default parameters and display mode. Using this information it loads the GUI manager for user operation. It handles parameters, which are Maximum Range Selection and Range Ring Selection for Host Centered mode and Range of Lat/Long and Maximum Area Selection for Lat/Long mode. It also provides facility for user to change the default settings.

2.5.1 Default Settings Handler

We have two files for settings. First file holds the default values for all user specified parameters and the display modes. Second file is the current file which is loaded with contents of the first file at start-up. When user changes any of the settings they are visible in the current file. This module also allows user to change the default settings.

2.5.2 Mode and Parameter Changer
When user wants to change values of any of the parameters control comes to this module.

3 System Implementation

The system is implemented in two modes.
On-line mode
Off-line Mode

3.1 On-Line Mode: In on-line mode, the RADAR data is received through the MIL-STD-1553B bus using BUS Monitor mode from the appropriate memory location. The TARGET aircraft's position and heading is displayed using the RADAR and UHF data inputs. The position of the TARGET aircrafts is modified according to the new inputs.

UHF Antenna receiver uses TDM (Time Division Multiplexing) to get the incoming data from each TARGET aircraft for a specified time slot. When user enters a command its validity is checked and if it is valid, a proper action is taken.

3.1.1 Lat / Long mode: The profile of the HOST aircraft as well as that of the TARGET aircraft is displayed in the graphical display. Different color and symbols is used for HOST and TARGET aircrafts.

3.1.2 HOST centered mode: the HOST aircraft will be displayed at the center of the graphical display and the TARGET aircraft is displayed with respect to true north. A cone of ± 60 degrees is displayed with respect to HOST aircraft. At the background map is displayed to show the actual

position of flying. 2-D display is provided to show the latitude / longitude and altitude position of the aircrafts.

HOST and TARGET aircrafts flight information, such as position, altitude, speed, heading and range from the HOST aircraft can be seen.

3.2 Range / Distance and Bearing Calculation

3.2.1 Range Calculation

To compute the great circle distance between two pairs of latitudes and longitudes i.e., between Hack and Target, the formula is

$$d = a\cos\left[\begin{array}{l}\sin(LatH\ x\sin(LatT) + \cot(LatH)\\ x\cos(LatT)x\cos(LonH - LonT))\end{array}\right]$$

where d = distance between two aircraft's in radian

3.2.2 Bearing Calculation

Bearing tells you what way to go. It is defined as the angle measured horizontally from the north to the current direction of travel. North can be true north or magnetic north. The bearing formula is

$$c = a\cos\left[\frac{\sin(LatT) - \sin(LatH)x\cos(d)}{\cos(LatH)x\sin(d)}\right]$$

where c course or bearing

3.2.3 Degree Conversion

The range and Elevation values are in radians and these data are converted back to degrees (ddmm.mmmm). In the real environment, the display should be in degrees for the easy understanding of information. This is done by using the following formula,

Degrees = radians x 5.2957795

To convert back to the form ddmm.mmmm , save dd, multiply .dddd by 60, and add the exponent to the result, yielding mm.mmmm. Then concatenate the saved dd, resulting in ddmm.mmmm

3.2.4 Data conversion to screen co-ordinates

The calculated values are plotted on the display screen using the window to viewport conversion. The actual data are in the world co-ordinates. It

should be converted into screen co-ordinates, and range, bearing values are plotted on the screen for the targets with respect to the hack aircraft.

The formula for window to viewport transformation is ,

$$X_s = \frac{V_{xr} - V_{x1}}{W_{xr} - W_{x1}} (X_w - W_{x1}) + V_{x1}$$

$$Y_s = \frac{V_{yt} - V_{yb}}{W_{yt} - W_{yb}} (Y_w - W_{yb}) + V_{yb}$$

where,

X_s -x coordinate value of screen

Y_{s-y} coordinate value screen

X_{w-} x coordinate value of window

Y_{w-} y coordinate value of the window

V_{xr-} Viewports x coordinate right

V_{xl-} Viewports x coordinate left

V_{yt-} Viewports y coordinate top

V_{yb}-Viewports y coordinate bottom

W_{xr-} Windows x coordinate right

W_{xl-} Windows x coordinate left

W_{yt-} Windows y coordinate top

W_{yb-} Windows y coordinate bottom
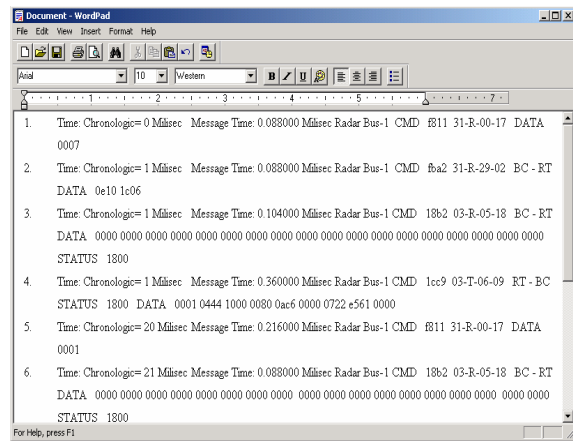
Fig. 3.1 RADAR File
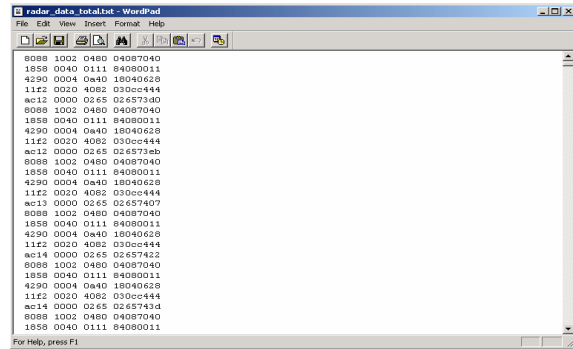
Fig. 3.2 4-R-1-1 & 4-R-2-30 parsed file with all message groups
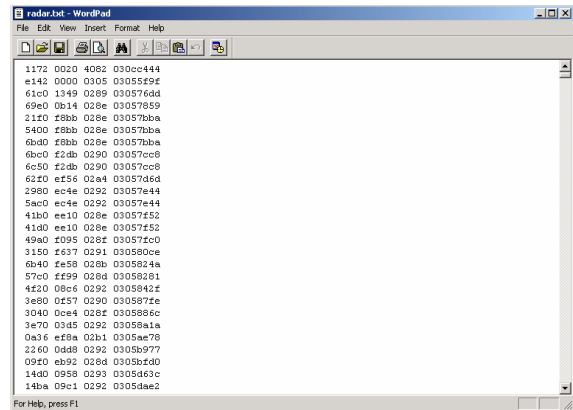
Fig. 3.3 4-R-1-1 & 4-R-2-30 parsed file with only valid message groups

Now this file is parsed line by line to get the time tag information and other information such as speed, azimuth, range etc., are extracted and displayed on the GUI with aircraft positions.
The hack centered mode, the user can provide the required number of targets in the displayed window that is shown in fig 3.4.
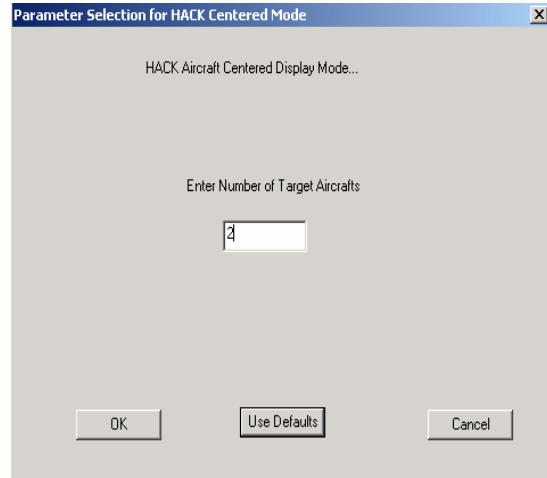

Figure 3.4 Hack Centered Mode

Figure 3.5 Map display

Fig 3.5 shows the map of the city showing the state Karnataka. It also shows some of the districts of Karnataka Tamilnadu and Andra.
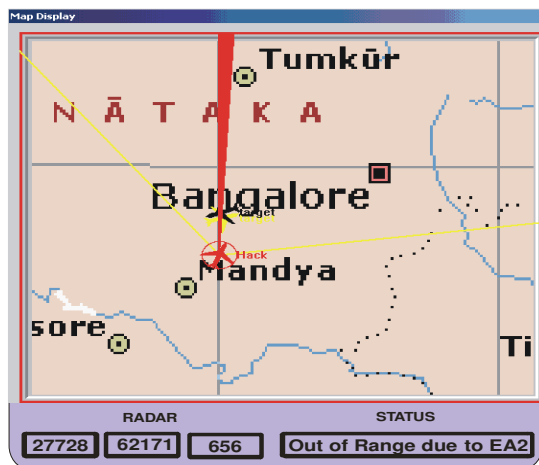

Figure 3.6 target tracking with host aircraft

Fig 3.6 shows the complete window during the flight with the below. It also shows the Hack and Target aircrafts. There are two target aircrafts one indicated in yellow and other in black. They are overlapped. It is to indicate that the two aircrafts can be in the same longitude and latitude but in different altitude. The yellow line beaming out of the Hack aircraft indicate the range of the azimuth in which the Host aircraft is looking for the Target air craft.

Tote window shows the RADAR data along with the status of the specified place. The first one is with

in the range with the mentioned longitude, latitude and the altitude. The second location is out of range.

3.3 Off-line Mode: In case of Off-line mode the user will be prompted for an input dialog box requesting a RADAR file. After the user selects a valid RADAR file, each and every line of the file is read by the system. After parsing the entire file for 4-R-1-1 and 4-R-2-30 messages, valid data is extracted into a file. This contains all the valid RADAR data.

Fig 3.7 shows the map with host in red colour and target in yellow colour. The circle around the host indicates that the host will be able to identify the objects/target aircraft in that radius. The tote window shows the required data that is captured and interpreted.
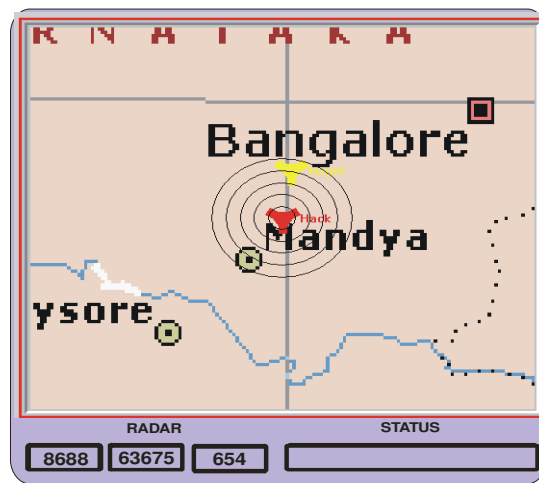

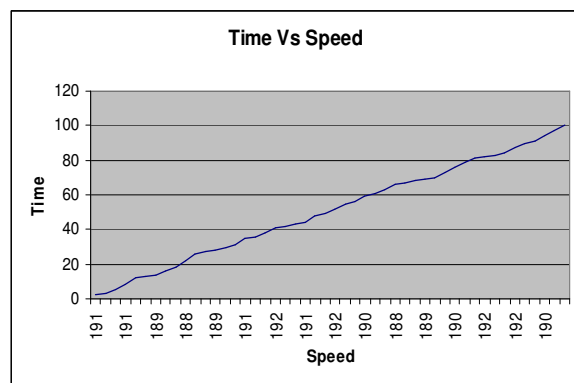Figure 3.7 Analysis in off-line-mode

Fig 3.8 Time Vs Speed

Using this information the graphs are plotted to verify the violated spots. The graphs for altitude and speed with respect to time are shown. Other graphs such as longitude, latitude, azimuth with respect to

speed can also be plotted for verification and precise result.

It is observed that the time interval during which the data is extracted and plotted, the speed linearly increases with time.
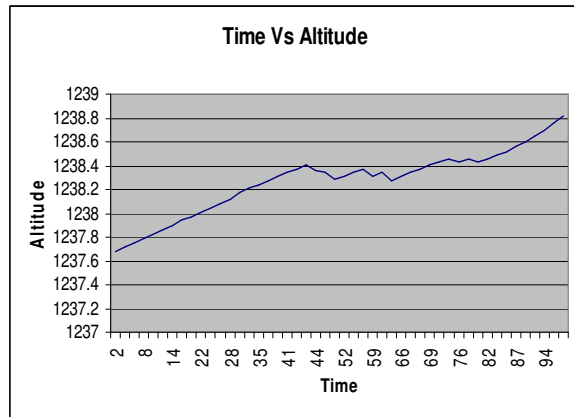

Fig 3.9 Time Vs Altitude

The figure 3.9 shows the Time Vs Altitude. It shows the linear growth of the altitude at the initial time interval and later on there is a small variation and finally there is increase in the altitude. This indicates that there is a steady and normal flight characteristics.

4. Conclusion

This system will help the flight test engineers and pilots to find out the position of the target aircraft and display the range and bearing of the target aircraft. It could be used by the test pilots during the on-line mode. During the offline modes, the validation and violation of the pilots' trajectory, altitude, speed, longitude and latitude can be traced. Various tests have been performed to scrutinize the validation of each data and the errors were spotted out and then finally cleared in a sophisticated manner.

The plotted graph is obtained after extracting the real time data on 24/3/2008.

5. References

[1] C S M Doake, H F J Corr, A Jenkins, K W Nicholls and C Stewart British Antarctic Survey, Natural Environment Research Council, Madingley Road, Cambridge, CB3 0ET, UK "Interpretation of polarimetric ice penetrating radar data over Antarctic ice shelves''.

[2] E. M. Atkins, R. H. Miller, T. VanPelt, K. D. Shaw, W.B.Ribbens, P. D. Washabaugh, and D. S. Bernstein, ''Solus: An Autonomous Aircraft for Flight Control and Trajectory Planning Research,'' *Proc. of the American Control Conference*, pp. 689-693, 1998.

[3] S. Fürst and E. Dickmanns, ''A Vision Based Navigation   System for Autonomous Aircraft,'' Robotics and Autonomous Systems 28, pp. 173-184, 1999.

[4] Truitt, R.B. Sanchez, E;Garis, M. Autotestcon 2004. Proceedings Volume, Issue, 20-23 Sept. 2004 Page(s): 117 – 123 ''Using open networking standards over MIL-STD-1553 networks''

[5] Vicen-Bueno; Rosa-Zurera; Cuadra-Rodriguez; de-la-Mata-Moya; Lopez-Ferreras. WSEAS-Transactions-on-Signal-Processing. Feb. 2006; 2(2): 295-301. "Radar detection of exponential targets in Weibull clutter and noise based on multilayer perceptrons''

[6] Marcin Muszkowski, Robert Lesnik, Edward Sedek   WSEAS-Transactions-on-Communications. Oct. 2006; 5(10): 2001-4 ''Radar Coverage Calculations Based on Antenna Characteristics''

[7] Bradford W Parkinson and James J Spiker (1996) Global Positioning System: Theory and Applications Volume-1, American Institute of Aeronautics and Astronautics, Washington.

[8] MIL-STD-1553 Tutorial

[9] Radar Receiver Programmer's Guide.