ABSTRACT

The DoD has recently mandated new acquisition, or procurement strategies for the research and development community. The policy includes using Non-Developmental Items (NDI) whenever feasible, as well as avoiding the use of proprietary sources. Such practices lesson time from specification to operation, ease of extensibility and progressive maintainability.

In this paper we discuss the NDI and in-house designed test assets developed and implemented for testing the pods. Our time from specification to test was less then one year.

KEY WORDS

Semi-Active Seeker, Doppler Track, Angle Track, Telemetry, Instrumentation, MIL-STD-1553

INTRODUCTION

Semi-Active Seekers

The Pod Mounted Seeker Program (PMSP) Lab has a small anechoic chamber and a secure network of computers for calibration, maintenance, and preflight operation of Captive Carry pods. The PMSP Lab test assets are built exclusively on either in-house design products or NDI, i.e.; there are no proprietary sources. The test assets include an avionics simulation system, an RF stimulation and simulation system, a GPS time distribution package, and real-time telemetry and recording system.

The pods carry semi-active seekers that capture angle and Doppler tracking data from a target aircraft. The data is later packaged for customer delivery and/or analysis. There are two pods and each use a unique tracking scheme, although both use the same theoretical techniques. The pods house Surface to Air semi-active seekers. Each employs monopulse angular and Doppler velocity tracking techniques.

Angle Track

The angle tracks are acquired via phase monopulse radar using a quadrature of sum (S) and difference (D) channel vectors. The figure, shown below, depicts a simple phase comparator radar channel. The S channel receives amplitudes from at least two azimuthal and elevation beams, A and B : S = A + B. The D channel is D = A – B. The amplitude through both ports is roughly the same. The phases differ if the target is located off-boresight. The phase ‘shift’ is \(2\pi \cos \alpha / \lambda\), where \(\lambda\) is the received wavelength. The difference, D, is generated by a comparator that phase shifts port A by \(\pi\) radians followed by an addition to port B. The sum has no phase shift. The channel may be modeled in the complex plane as \(S \pm D\). These signals are sent to the receiver as quadrature signals. This results in a complex signal, \(D = j(A–B)\). It is easy to show that the real part of the ratio (D/S) is proportional to the direction \(\cos \alpha\) to the target angle off-boresight.
Doppler Track

The Doppler tracks via comparison of a rear reference signal from a ground illuminator and a front-end target return from the same illuminator. The Doppler is calculated in the pods via comparison of a rear reference channel antenna and a front-end (target) receiver antenna. The reference antenna receives an illuminator beam of ‘known’ frequency and the front end receives the target’s reflection of the illuminator. For \( v_o \) & \( v_i \ll c \) the observed frequency \( (f_o) \) is

\[
f_o = f_i(1+\beta_o)/(1-\beta_i).
\]

\( v_o \) is the observer’s velocity; \( v_i \) is an illuminator’s velocity, \( f_i \) is the illuminator frequency. For a seeker assume the target’s velocity \( (v_t) \) is positive towards the seeker’s front-end receiver, then

\[
f_{sf} = f_i(1+\beta_s)/(1-\beta_t).
\]

Note that if \( v_t \) or \( v_s \) increases the observed frequency increases. Now \( f_t = f_i(1+\beta_t)/(1-\beta_i) \), so

\[
f_{sf} = f_i(1+\beta_t)/(1-\beta_i)(1+\beta_s)/(1-\beta_t).
\]

For the seeker’s rear reference receiver

\[
f_{sr} = f_i(1-\beta_s)/(1-\beta_i).
\]

The difference in the seeker’s front and rear signals is

\[
\Delta f_s \equiv f_{sf} - f_{sr} = f_t + f_s - f_i.
\]

Substitution and simplification yields:

\[
\Delta f_s = 2f_i(\beta_s + \beta_t)/(1-\beta_i)(1-\beta_t).
\]

Where \( \beta_s = v_s/c \) is the Doppler ‘weight’, \( v \) is the line of sight (LOS) ‘source’ speed and \( c \) is the speed of light in vacuum. The LOS is a ‘unit’ radial between target and the seeker front-end. Acceleration can be added to the velocity in set ‘acceleration’ increments.

Control Hardware

All control is coordinated by or through a Power PC (PPC) card on a Versa Module Eurocard (VME) bus. The PPC has three command and control (C&C) external communication channels: Serial (RS-232); Ethernet; and MIL-STD-1553 bus.\(^1\) There is also a telemetry (TM) channel (RS-422-to-PCM [pulse code modulation]) that links the PPC and an S-band transmitter. The system control and data

\(^1\) The RS-232 and Ethernet both use File Transfer Protocol (FTP) for pod-workstation interfacing, as well as for pod-rack communication. The MIL-STD-1553 is simulated in the PMSP Lab with an SBS© PASS-1000 system.
acquisition is coordinated via a Real-Time Operating System (ROS) on the PPC. All communication, C&C, and data acquisition transmit through the PPC.

Each pod has four primary modes to control – Power ON/OFF, Standby, Slave, and Track (or Designate). Pod modes are distinct from seeker modes. A ground control station commands via a TM duplex link. We use this link in the PMSP Lab with an Avionics simulator, discussed below.

The Power Monitor board converts aircraft +28VDC to standard integrated circuit (IC) logic & signal conditioning levels and also monitors the power levels. All switching is via +28VDC relay, a watch dog timer on this board that monitors the acquisition cycle.

The primary control logic signals that interface the PPC with the seekers are on PC boards (PCB) called Slave and the Digital Output boards.

The Digital Output board permits the interface of C&C software and hardware via solid-state switches. These solid state switches receive signals directly from the PPC via the VME bus. The modes are unique to the pods, e.g., on the SADS VI some of the modes are RDY, LWOL Lock, HST, EOB, NZI, etc. The modes are not discussed in detail here.

The Slave board is the primary command interface for ‘Track’ or ‘Designate’. The ‘Designate’ values are not simple C&C signals – the circuit outputs designate commands based on real-time time-space-position information (TSPI) data processed by a Kalman filter with GPS and INS data parameters, and a 9-degree of freedom kinematics model designed by Georgia Tech Research Institute (GTRI).

Instrumentation Hardware

Each pod is fully instrumented for data acquisition of track data. There are two Digital Input and two Analog Output boards. The TM is an RS-422 signal from the PPC, conditioned via ICs.

The Digital Input boards are the discrete digital to analog converters (DAC); they collect data from the seekers. There are 32 channels - not all are used. The discretes are all transistor-transistor logic (TTL) levels. Some signals specific to the Improved Homing All the Way Killer (I-HAWK) pods are target detect, noise detect, boost strobe, etc.

The Analog Input boards are 16 channels each with identical conditioning circuits except for gain scaling. An active LP anti-aliasing filter follows the gain. Some of the signals on SADS VI are inner position, outer position, Doppler sweep volt, Doppler disc err, rear IF level, etc. These are not discussed in detail.

The TM channel is a 63, 16-bit word format that is encrypted. The TM system receives input from the TM signal conditioning ICs on the Power Monitoring/Miscellaneous board. The board’s front-end is driven by an RS-422 port of the PPC, the rear end is a PCM signal for the S-band transmitter.

The test data is also recorded on a Solid State Disk (SSD); the files are file allocation table-formatted and may contain seeker data, as well as TSPI and MIL-STD-1553 bus traffic.

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2 The PPC is the controller of what is called a ‘Computational Card Cage’ (CCC). The CCC is a 15-slot VME system.
Test Equipment

RFTS

The RF Test Suite (RFTS) is a suite of RF generation and acquisition equipment, a TM receive system, an Avionics simulator, and a GPS time distribution system. Communication is via Ethernet and IEEE-488. ³

The RF₁ is a network designation for a computer that controls the avionics simulation intermediate frequency (IF) via a modified SBS© PASS-1000 application. This application permits MIL-STD-1553 bus control, as well as full Real Time Kill Removal (RTKR) pod⁴ and MIL-STD-1553 bus simulation. The Sim application, as it is called, was customized by GTRI to display pod particular information.

The Sim has six primary fields of information:

- Modes, Telemetry, Recording, Illuminator;
- Faults, Target GPS ID;
- Seeker Commands;
- Track parameters;
- Status;
- Mode Commands.

When calling the Sim avionics application, the operator selects the IF based on pod type, test type, and whether a full avionics, or RTKR pod simulation is required. The RTKR pod simulation may be run only when the pod is on the wing pylon with the actual MIL-STD-1553 bus IF active. The simulation IF also permits mode selection, i.e., power ON/OFF, Slave, Standby, Track (Designate), TM ON/OFF, Record ON/OFF, etc.

³ Each computer has a serial port (RS-232) designated to monitor RFTS uninterruptable power supply. The health and status of the power system is shared via an Ethernet.

⁴ RTKR is a range pod designator.
Shown below is a serial port communication IF. This terminal permits total control of the avionics, plus additional IF commands needed in the PMSP Lab. The terminal is a standard IF available with the NDI operating system.

The RFTS and pods use GPS time receiver systems. The GPS time is captured and distributed to all RFTS and pod computers via a Brandywine™ card and a time distribution software kit called TimeSync®.

The RF_2 is a computer that controls RF field generation, switching, and Doppler signal simulations. All field generation and simulations are controlled via a RF Test Executive (RTEx) ⁵. There are five fundamental RTEx modules used to control the equipment:

- Target return (free space)
- Reference (Illuminator injection or free space)
- ECM (free space)
- Modulation on Illuminator
- RF Switch (to antenna & acquisition units)

Below you see the IF the developer would use for loading and running RF Doppler and angle track simulations. The sequence of modules that make up this test are shown in the display window on the left; a description is shown in the upper right window. The test run status will appear in the lower right display. The ‘Switch’ control appears on the lower right and also ‘acts’ as a display of the present switching scheme. The menu at the top is a set of buttons for loading and unloading test sequences, as well as for logging in and out and even modifying and/or creating test sequences. The colored buttons are for direct control of the RF equipment displays, status and health, as well as soft resets. The RF_Out_Ctrl permits a user to control when the actual radiation will happen for each source. In this case the ECM is shown as the source.

⁵ RF_2 controls the RF equipment via the General Purpose Interface Bus (IEEE-488).
The operator IF has a subset of these controls that permit loading, unloading sequences, running the sequences, and controlling the ‘RF out’.

RTEx coordinates the execution of signal modulations, power and frequency field characteristics, and all the RF switching necessary to steer Doppler simulated signals to antenna, injection ports, and RF acquisition units via software modules. These modules are not available to the operator, but a developer can access them for building test sequences, or even access from the RTEx for parameter changes.

Below you see a module for controlling the target RF characteristics. The modules are designed to permit interactive changes to the present test parameter sets. Each module has a full description of its use accessible via the main Windows menu. The controls are simple to use and intuitive.
The target and reference sources controlled by these IFs are HP83731b generators, the ECM source is an HP83711b. The modulators are HP33120a signal generators. The acquisition system consists of an HP8566b spectrum analyzer, an HP438 power meter, an HP54750a oscilloscope, and an HP5350b frequency counter. Each has an IF C&C module that may operate under control of RTEX, or under direct user control.

The RF_3 is the TM interface (IF) – this channel contains an SBS-Berg™ TM suite with a DataXpress® (DX) application IF.

With this IF you may call the DxSystem Controller by selecting the Control icon on the left, or by simply pressing the Start icon on the right. The Start icon calls the system controller, initializes the Current Value Table (CVT), the hardware controls for receiver, bit sync, and decommutator. The DxSystem Controller for running a decommutation system is shown below.

The DX IF permits real-time views of the TM data in the PMSP Lab, flightline, or even a range. The pods have TM ports for direct injection into a TM receiver on the RFTS. The TM hardware is a SBS/Berg® 4487 receiver, a 4422 Peripheral Component Interconnect decommutator with mezzanine bit sync. The pod formats are stored in a Microsoft® Access® database.

Development Workstations and Tools

The PMSP Lab has three development workstations: a Sun Sparc10 with the Solaris operating system that houses the VXWorks™ ROS development environment. There are also two Windows® NT 4.0 workstations. All PMSP Lab and pod computers are linked via Ethernet.

The ROS is VXWorks™, a Windriver™ product developed for the Solaris operating system. The Sun is a government asset that GTRI used to develop and modify pod control programs. The
programs are stored on board the PPC in flash; the transport from the Sun to the ROS is via an FTP port available on the PMSP Lab computers.

The RFTS and PMSP Lab development stations use a popular commercial operating system: WinNT4. The primary development environment on the WinNT4 operating system is LabVIEW™. The LabVIEW™ development environment was used for the RF simulation architecture.

The pod on-board storage is via a Solid State Disk (SSD). The SSD may be removed from the pods and docked in the RFTS. The disk may be written directly to CD for customer delivery, or analyzed on sight.

The applications for data reduction and analysis are a product of GTRI. This software package runs under the NT DOS prompt, it is called *Post-Test*. This IF parses data directly from the pod disk, e.g., it sorts by data type and/or time slices. The data can be ported to MATLAB® or even a spreadsheet application, e.g., EXCEL®, for analysis. We use the Post-Test for pod calibrations. Below you see the operator IF.

The data is stored in a ‘folder’ file structure visible to the WinNT4 operating system.

The PMSP Lab also has an AutoCAD® workstation. This workstation is used exclusively for modifying the schematic and wiring diagrams used to build the DAC C&C cards not available in the commercial market.

**Conclusion**

The testing, calibration, and maintenance of the captive carry pods requires detailed coordination of RF field sources, communication and telemetry interfaces, as well as analysis tools. There are now several commercial systems available that suit our needs. An effort has been made to build a system that relies on NDI products, and when necessary we have designed any unique products unavailable in industry using industry tools. This system was built in less then one year; upgrades and support for the software and hardware is guaranteed. Such systems are relatively easy to use, extensible, and supportable through industry upgrades and support, and so, cost effective, reliable and quickly operational.

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6 AutoCAD is a commercial product for design and drafting.
References:
