THE PERFORMANCE EVALUATION OF AN OFDM-BASED IP TRANSCEIVER AT EGLIN AFB

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ABSTRACT

The 46th Test Wing, 846th Test Support Squadron (846 TSS/TSI) at Eglin AFB is currently evaluating their airspace for the use of SOQPSK transmitters and receivers for telemetry. The Squadron will incorporate an IP-compatible OFDM transceiver from Teletronics Technology Corporation (TTC) that will provide a two-way communication channel for controlling configuration settings of the airborne SOQPSK transmitter and receiver. This provides an opportunity to evaluate the effectiveness of an airborne network instrumentation system and measure some critical parameters, with an opportunity to assess the performance and reliability of streaming telemetry and OFDM-based IP communication systems. This paper describes the experimental test setup created for this evaluation and summarizes the measurement and evaluation process.

Keywords

Instrumentation, IP Transceiver, Networking, OFDM, SOQPSK

INTRODUCTION

The increase in telemetry data rates and loss of available spectrum has caused the flight test community to look at ways to increase spectral efficiency and reduce multi-path interference. The Advanced Range Telemetry Modulation (ARTM) program was initiated and funded through the Office of the Secretary of Defense **(**OSD**)** to identify more bandwidth-efficient modulation formats suitable for use in aeronautical telemetry. The program selected a family of suitable waveforms to reduce the current PCM/FM spectrum usage by 50%. In addition to the need to assess the impact of geographic features on the robustness of the waveforms, it is desirable to measure the efficiency of the transmitters and receivers at multiple frequencies, such as the L1, L2, S and C bands. Given the cost per hour of flying test fighter aircraft, any means to reduce the number of flight hours required would provide a significant cost savings to this process. One approach to this problem would be to provide flight-capable dynamic control of multiple operational factors such as center frequencies, power levels, modes and frequency bands with the transmitter and receiver. This approach has the potential to allow for the characterization of chosen waveforms' performance throughout the range in a fewer number of airborne hours.

The 46th Test Wing, 846th Test Support Squadron (846 TSS/TSI) will utilize a network transceiver from TTC that has been in development for over two years. The Teletronics device augments a conventional serial-streaming telemetry system by providing an interactive two-way communication channel for controlling, monitoring and accessing a network-based instrumentation system within an aircraft. A network transceiver performs the same function as a conventional Internet router on the ground by bridging multiple independent sub-networks into a single communication domain. Providing a hub and spoke topology, the network transceiver allows for multiple aircraft to be connected into the ground network and utilized in the same manner as a Web site or a file server. Realizing these benefits, the 846th TSS/TSI will fly TTC's IP-compatible OFDM transceiver in order to establish a two-way communication channel for controlling the configuration settings of the airborne SOQPSK transmitter and receiver instrumentation package.

Once an IP-based communication link exists between the ground network and the airborne instrumentation package, real-time access to individual units on the test package is possible. However, the true benefits and flexibility of this capability is only realized if the individual components of the test package have network interfaces. When the decision was made to integrate the IP transceiver, it quickly became obvious that the instrumentation package should be extended to provide more networking capabilities that the 846th TSS/TSI could take advantage of from the ground. The existing Pulse Code Modulation (PCM)-based Data Acquisition Unit (DAU) was upgraded to include a network interface and a network-based high-speed camera sub-system to provide an experimental testbed for more sophisticated command and control opportunities. Flying an aircraft that includes a network-based instrumentation system provides an additional opportunity to evaluate the effectiveness of an airborne network instrumentation system on its own and measure some of its critical parameters, such as IEEE 1588 timing accuracy, packet latencies, and the ability to perform dynamic bandwidth assignment. More importantly, it provides an opportunity to assess, side-by-side, the performance and reliability of streaming telemetry and OFDM-based IP communication systems. This paper describes the experimental test setup created for this evaluation and summarizes the measurement and evaluation process.

TEST OBJECTIVES

The specifications of the instrumentation package were driven by the objectives of the experiment. The primary objective of this task is to characterize the suitability of replacing the existing PCM-FM telemetry sub-system used for flight test at Eglin with a newer system based on SOQPSK. In order to efficiently assess this objective, the experimental package was augmented with a networking component. This led to an expansion of our test objectives to include additional factors. The complete set of test objectives for our experiment is:

1) Performance of SOQPSK transmitters and receivers
    a. Air-to-ground RF links in high-dynamic environments
    b. Air-to-air RF links in high-dynamic environments

2) Performance of OFDM-based IP transceivers
    a. RF link and data transfer performance
    b. Command/response and real-time data latencies

3) Viability of network instrumentation systems
    a. Bidirectional command and control of instrumentation
    b. End-to-end latencies and bandwidth tolerances
    c. Topology adaptation within range networks
    d. Network (IEEE 1588) timing accuracy

4) Viability of network ASV systems
    a. Bidirectional command and control of cameras
    b. Real-time avionics or instrumentation data event-based triggering
    c. Real-time video for pre-separation assessment and camera management
    d. Post-separation download of camera images

5) L-, S-, and C-band transmitters and down converter evaluation

TEST SETUP

Four different test scenarios have been designed to complete the ARTM evaluation process. The first two scenarios will be a short distance ground-based test, where both ends of the communication links will be stationary. The third scenario will place one end of the link onboard a helicopter for a medium distance mobile test. The final and most complex scenario will add a third mobile endpoint to the communication network and will be hosted aboard two F-16 aircraft for long-range and high-speed testing. In order to minimize the number of hardware configurations required, it was decided that the first three test scenarios would use a common hardware pallet. The final test scenario would use the existing 46 TW 846 TSS/TSI Joint Range Instrumentation Pod (JRIP) that will be modified to allow for evaluation of the SOQPSK transmitter as well as provide evaluation of the new network-based instrumentation capability. The JRIP consists of five mechanical sections installed in a cylindrical tube with the same mass properties as an AIM-120 missile. Two different functional configurations would be created for the fourth scenario to allow for both air-to-ground and air-to-air communication channels. The first configuration will be utilized for validation of the airborne SOQPSK transmitters, airborne SOQPSK receivers and the 46 RANG ground SOQPSK receivers. The second configuration will be utilized for validation of the network OFDM-based transceiver instrumentation. Both configurations are combined into a single network when instantiated on the common hardware pallet. The functional block diagram for the pallet is illustrated in Figure 1:

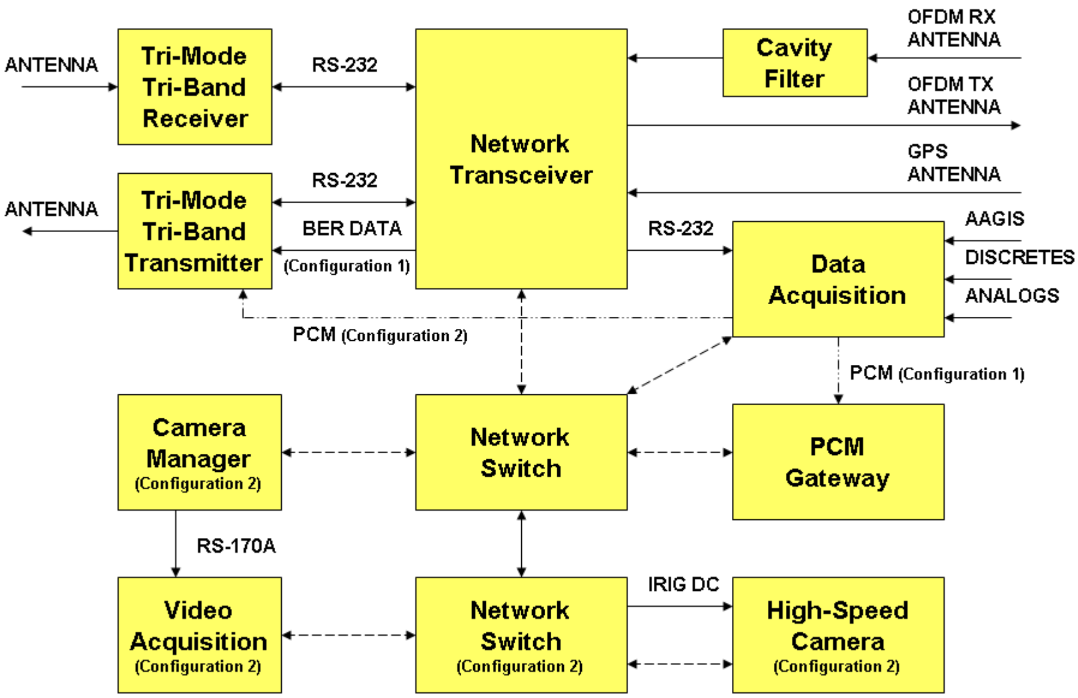

Figure 1: Test Pallet Block Diagram

The nXCVR-2030B-1 network IP transceiver provides the two-way ground-to-air link between the test pallet and the ground station. This device is designed to act as a wireless router for communicating IP packets between the instrumentation network and the ground network infrastructure. It uses a TDMA-based MAC layer to provide guaranteed bandwidth and QOS assignments (dynamically controlled) to communication protocols flowing to and from the ground. The transmitter power and modulation is automatically controlled based on measurements from remote stations regarding RSSI (signal strength) and LQI (link quality) indications. Supported bit rates range from 6 to 36 megabits/sec.

The network transceiver has been modified for this experiment to provide additional interfaces to the test pallet beyond the standard gigabit Ethernet interface. Upon command, the transceiver can output a PN15 BER test pattern for input into the tri-mode tri-band transmitter. The transmitted BER test pattern will be fed into a BER tester on the ground to validate the performance of the telemetry link. The clock rate of this test pattern can be dynamically changed to values between 10 kHz to 20 MHz. The BER test pattern can also be changed to a fixed pattern of all zeros or ones. Finally, it can be converted into a normal CH4 PCM output containing operating statistics from the transceiver itself for diagnostic purposes. In the second configuration, the output of the transceiver is replaced with the PCM output of the MnACQ-2000, a networked data acquisition device. Two RS-232 interfaces are provided that are connected directly to the tri-mode, tri-band transmitter and receiver; this allows for telnet access from the ground to the serial console of each device for real-time configuration and monitoring. A five-port 10/100 Mb/sec IEEE 1588 switch, the NSW-5FT-TGE-1, is connected to the gigabit Ethernet interface of the transceiver to interconnect the network components of the test pallet. In the case of the second configuration, two switches are required to handle the extra devices. The MnACQ-2000 is configured with a set of analog and bus signal conditioning modules to allow for acquisition of data for accelerometers, thermocouples and serial buses. Refer to Figure 2 for a photograph that depicts the ARTM integration test pallet.

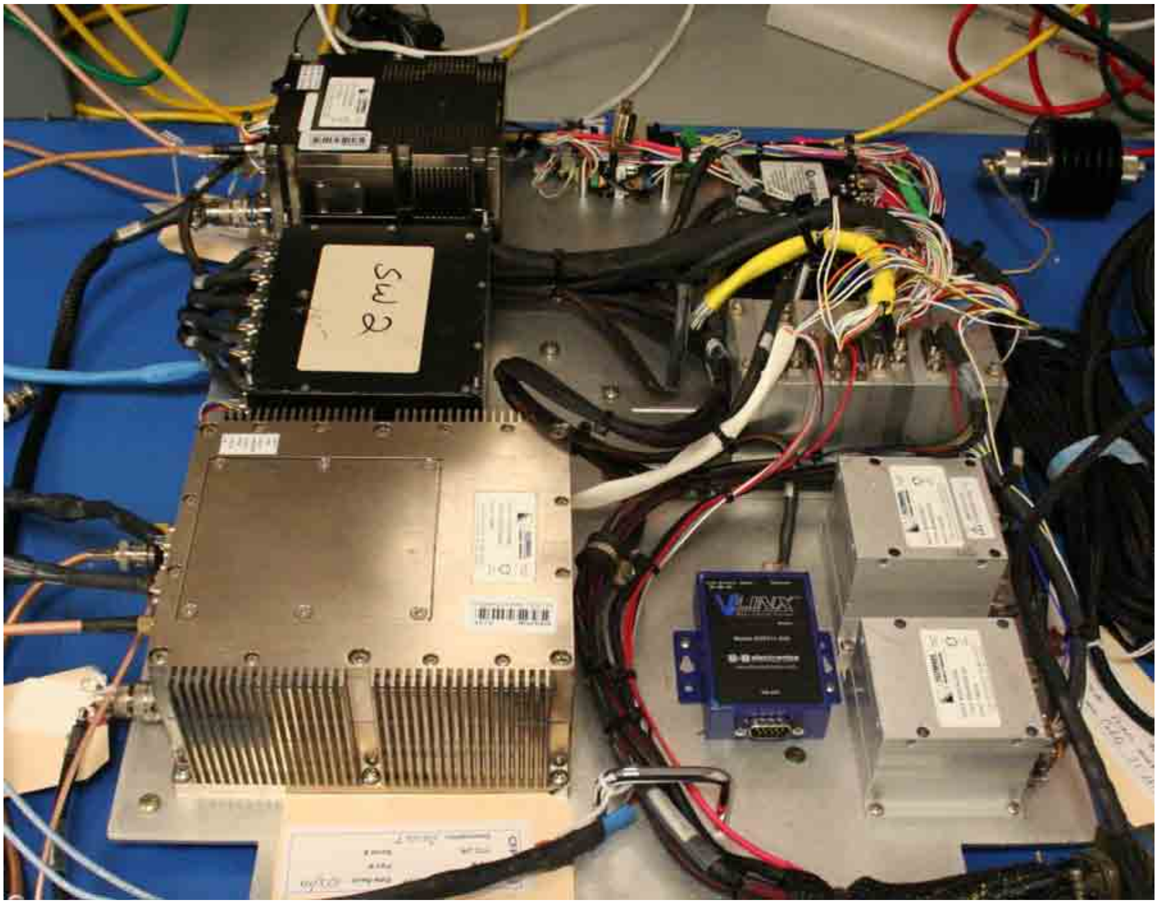

Figure 2: ARTM Integration Test Pallet

In configuration 2, a high-speed camera (nHSC-20-S3R-1), a camera manager (nMGR-2000), and an analog video acquisition node (MnVID-2000) are added to provide the capability to control and download images from a network device over the network transceiver link. The camera manager provides operational services for networked high-speed cameras, such as synchronized triggering, pre- and post-views of images, and transfer of images between the cameras and the recorder. In this configuration, the camera manager takes real-time frames from the camera, adds a time and status overlay to the image, and outputs the data through a RS-170A interface. The MnVID-2000 digitizes the RS-170A at 30 FPS, encodes the video into MPEG-2 transport packets and multicasts the data into the network. The network transceiver can be configured to route the multicast packets through the wireless link to the ground for real-time viewing. Finally, the MnACQ-2000 can output its acquired parameters as either network packets or PCM data, the MnPCM-2000 gateway allows for a comparison of the latencies introduced by sampling the same parameter either in a streaming telemetry link or as a packetized communication channel.

TEST SCENARIOS

Four test scenarios are planned for the instrumentation system built for the ARTM transmitter and receiver. The first test scenario, shown in Figure 3, is a lab-based setup designed primarily to complete hardware and software integration, system programming, verify cabling, and validate the planned test measurements. All RF connections are made using shielded cables and attenuators.

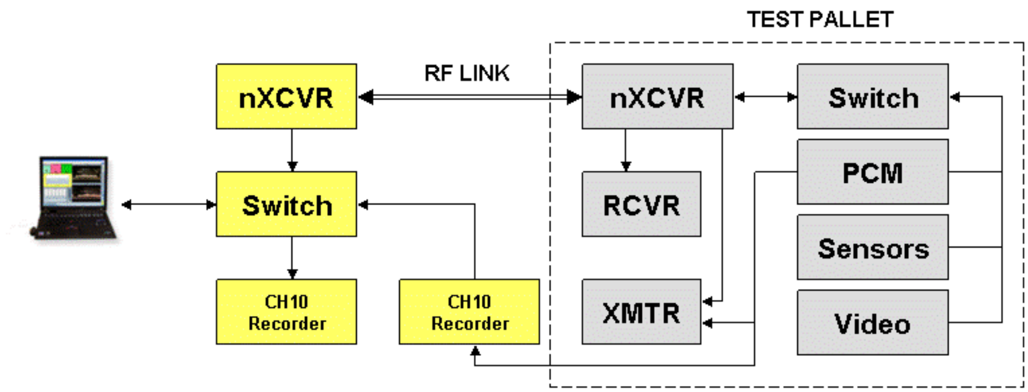

Figure 3: Lab Test Bench Configuration

The second test scenario, shown in Figure 4, is a static outdoor test where the test pallet and the ground station are separated by twelve miles. The two primary goals of this test are to verify the operation of the network transceiver over a long distance and to validate the ground station antenna infrastructure for OFDM transmit operation.

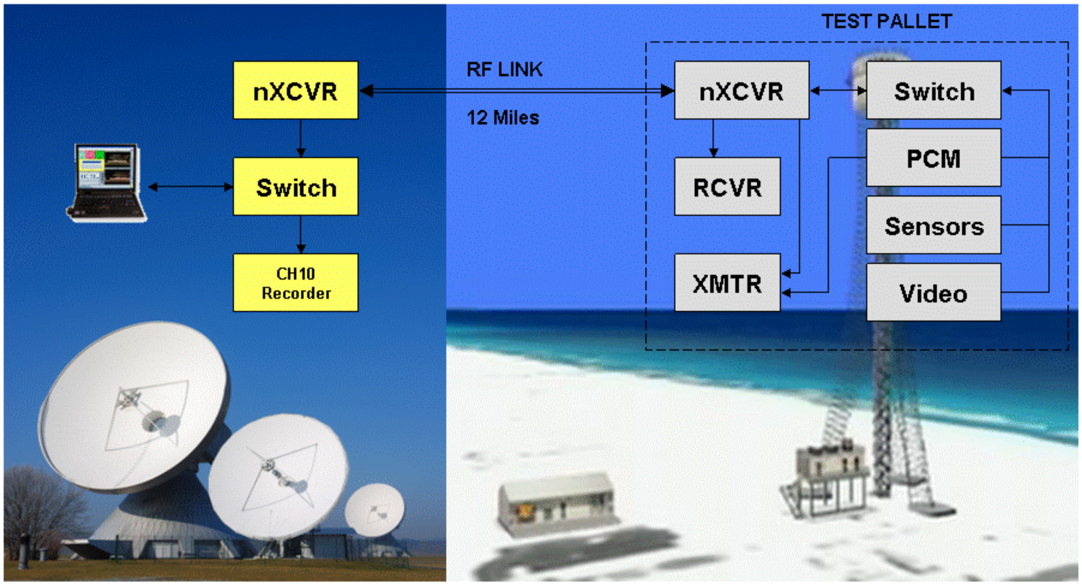

Figure 4: Twelve Mile Tower Test

The integration of the ground station with the transceiver is seamless, as the dual-feed antenna configuration allows the transceiver to operate on one feed with the reception of the telemetry link on the second feed. As shown in Figure 5, the nXCVR-2130A-1 operates in upper S-band while the ARTM transmitters operate in lower S-band. The ground station antennas steer the RF signals to the proper equipment feeds using triplexers and an RF switch that provides up to 80 dB of isolation. The only apparent concern from the ground perspective is the collocated tracking antenna and the transceiver transmitter gain. Typically these ground antennas do not radiate and there was a concern that the transceiver uplink transmission wattage may damage nearby tracking antennas if they are pointed into each other's look-angle. During the performance of the tests described in this paper, the co-located antennas will be pointed away from the transmitting dish to avoid any possible damage.

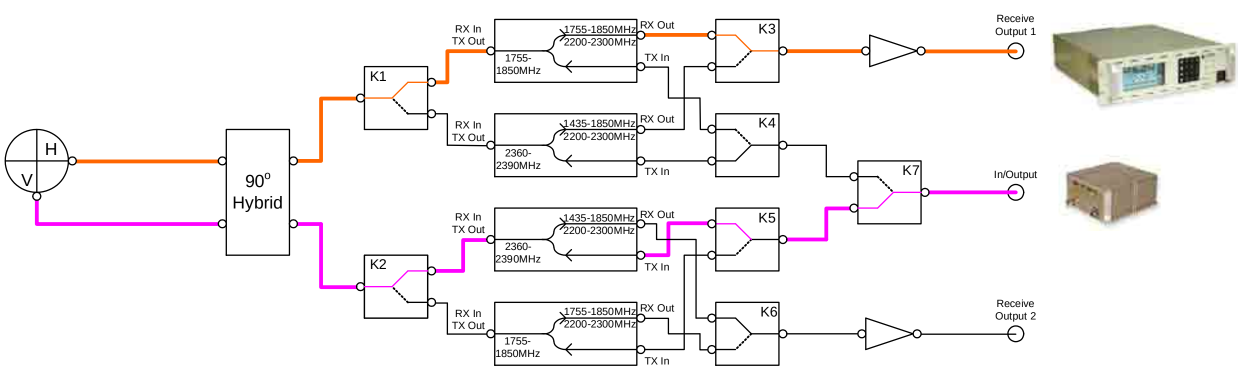

Figure 5: Ground Station Configuration

The third test scenario will be the first airborne test. A helicopter will be outfitted with the test pallet and necessary antennas to enable a short range (5-25 miles) airborne test to assess the impact of low-altitude, low-speed multi-path effects on the performance of the tri-band, tri-mode transmitter and the network transceiver. For this effort, the test pallet will be installed on a plate and mounted to the floorboard of the vehicle (see Figure 6). Power and access to the GPS RF signal will be accomplished by interfacing to the aircraft existing T-2 instrumentation interface and three antennas (OFD TX/RX and SOQPSK TX) will be mounted external to the vehicle. The OFDM/ARTM plate is designed to be able to be removed from the aircraft on a mission-to-mission basis. The design provides for a one hour maximum time to configure or reconfigure the helicopter.

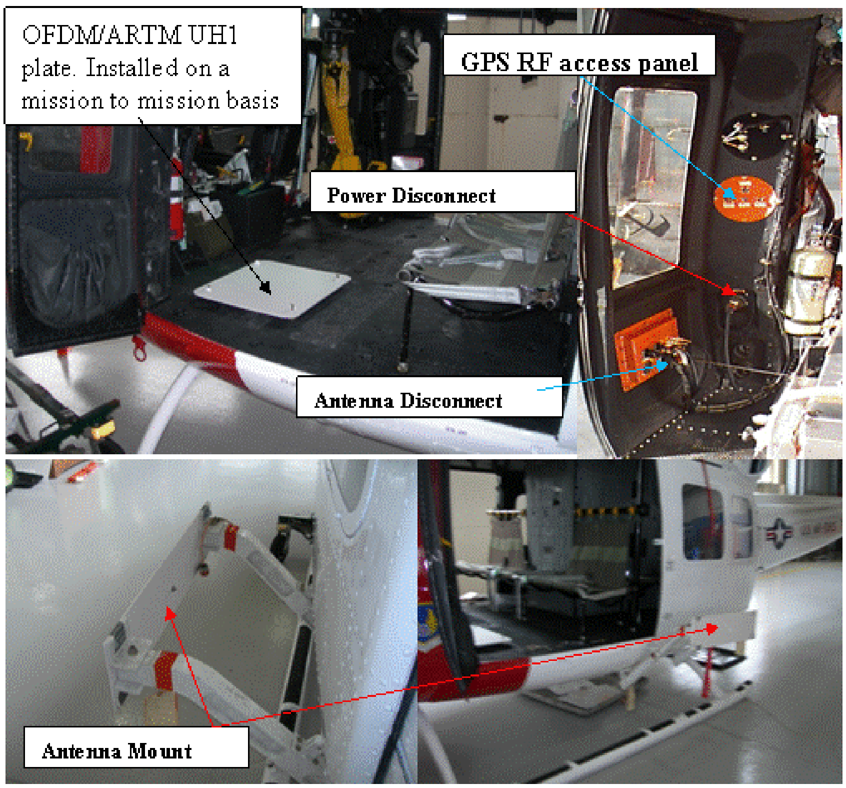

Figure 6: Helicopter Test

The final test scenario involves the use of two JRIP pods (see Figure 7) that contain the components of the test pallet arranged into two new mechanical and wiring configurations. Both configuration 1 and configuration 2 of the test pallet will be utilized in the form of two JRIP test pods, each mounted on the wing tip of an F-16 and flown at distances of up to 150 miles from the ground station.

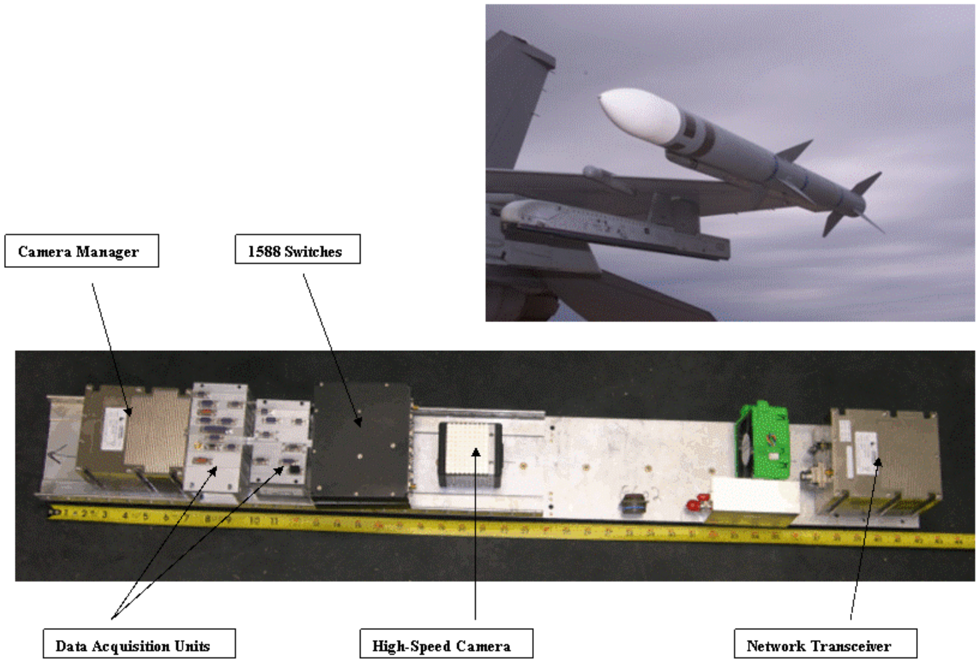

Figure 7: JRIP POD

This will be the most complex of the four test scenarios, as two-way communication will be maintained with two aircraft at the same time, in addition to the ARTM transmissions. Additionally, aircraft-to-aircraft communication will be tested using an ARTM transmitter and receiver.

TEST MEASUREMENTS

The test metrics to evaluate the usefulness of SOQPSK-based modulation schemes and the OFDM-based IP transceiver at Eglin are defined below:

- Mapping the received signal strength and link quality estimators of both SOQPSK and OFDM over varying terrain, distance and altitude.

- Measuring and characterizing the parameter delays of PCM and Ethernet data by comparing the timestamps embedded in the captured data versus the timestamps associated with the received data on the ground.

- Instrumentation command response delta times by measuring latency from a command send from the ground to the response time from the instrumentation system via both the PCM and Ethernet communication channels.

- Received network packets versus received SOQPSK PCM data in the form of Bit Error Rate (BER) will be measured using the random and fixed data formats.

- Comparison of the Received Signal Strength (RSSI), Bit Error Rate (BER), achieved data rates, and distances/altitudes between the OFDM and the Standard Telemetry Modulation schemes (PCM/FM and SOQPSK).

- Network bandwidth saturation (using PCM, video, command/response, and SNMP) by flooding the network-based transceiver with data while measuring both error rates and latency to determine constraints on the system performance.

- Evaluation of the minimum channel spacing between the OFDM Transceiver against the Standard Telemetry Modulation schemes (PCM/FM and SOQPSK) in an actual air to ground test.

- Compare the bandwidth efficiency in terms of data rates versus occupied bandwidth between the OFDM Transceiver against the Standard Telemetry Modulation schemes (PCM/FM and SOQPSK) in an actual air to ground test versus a theoretical analysis.

- Real-time ground software performance is an objective measurement using a real-time software visual display capability with the remote control/programming capability of the test pallet by a test technician using the ground station terminal.

CONCLUSION

The Advanced Range Telemetry Modulation (ARTM) and OFDM evaluation program by the 846th TSS/TSI offers a unique opportunity to fly a streaming SOQPSK telemetry channel and a bidirectional OFDM communication link side by side in the same aircraft. Dynamic control of factors such as frequencies, power levels, modes and frequency bands from the ground should allow for characterization of SOQPSK throughout the range in a fewer number of airborne hours. We expect to complete the ground-based portion of our testing by the end of July, with the airborne portion of the testing complete by September. The results of the testing should be available for presentation at ITC 2010.