INTEGRATION OF S-BAND FQPSK TELEMETRY TRANSMITTERS AND GPS-BASED TSPI SYSTEMS WITH CLOSELY SPACED ANTENNAE – A SUCCESS STORY

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ABSTRACT

Modern spectrally efficient telemetry transmitters are beginning to find their way on a variety of airborne test platforms. Many of these platforms also include Global Positioning System (GPS)-based Time-Space-Position-Information (TSPI) instrumentation systems. Due to space and other limitations, many of these platforms have demanding antenna placement limitations requiring closely spaced antennas. This paper describes steps taken to identify and mitigate potential interference to GPS-based TSPI instrumentation systems by these new technology transmitters. Equipment characterization was accomplished to determine interference potential of the proposed new transmitters and susceptibility of several GPS TSPI receivers. Several filtering techniques were identified as possible solutions to the anticipated interference problems. Telemetry (TM)/GPS system mockups and laboratory tests of the same were accomplished. Open-air testing was then accomplished to validate laboratory results. Finally, on aircraft tests were accomplished prior to performing any aircraft system modifications. Results of these test efforts are presented for others to consider when planning similar modifications to other platforms.

KEYWORDS

FQPSK Transmitter, GPS Receiver, TSPI, ARDS Plate, Radio Frequency Interference, Antennas

INTRODUCTION

Increasing demands for telemetry data combined with a shrinking amount of available spectrum have driven many flight test programs to seek out more efficient means for telemetry data transmission. The F-XXX program has chosen to implement a new modulation method, Feher's Quadrature Phase Shift Keying (FQPSK)-B, developed under the Central Test and Evaluation Investment Program (CTEIP) Advanced Range Telemetry (ARTM) Program. L-Band and S-Band FQPSK-B transmitters were procured from Herley Industries for testing and ultimately integration on the aircraft. The antenna arrangement on the F-XXX presents a unique and difficult situation with respect to Radio Frequency Interference (RFI) to the GPS TSPI system from the telemetry transmitters. Knowing this would be a significant challenge, we procured a variety of filters to be used for testing. In addition to the technical challenges, access to the aircraft for testing drove us to find other means to test various equipment configurations to cut down on the amount of aircraft down time required for testing and modifications. This paper describes the process we used to evaluate system performance off the aircraft and ultimately the on-aircraft test performed prior to permanently installing the equipment for flight test use.

BACKGROUND

Figure 1 represents the initial configuration of the aircraft telemetry transmitter and TSPI GPS equipment. The system employed a pair of Aydin T610-200 tunable S-Band FM transmitters. The GPS system is an Advanced Range Data System (ARDS) High Dynamics Instrumentation Set (HDIS) plate which utilizes a 5-channel GPS receiver. There were no transmitter filters used on the initial system and the GPS antenna utilized an outboard filter/(low noise amplifier (LNA) assembly. Figure 2 is a picture of the top antenna panel depicting the closely spaced antennas. The TM blade antennas are spaced approximately 9 inches apart with the GPS antenna centered between them. The small white button antenna is a beacon antenna. There were no noticeable GPS interference problems with the S-Band pulse code modulation/frequency modulation (PCM/FM) system.

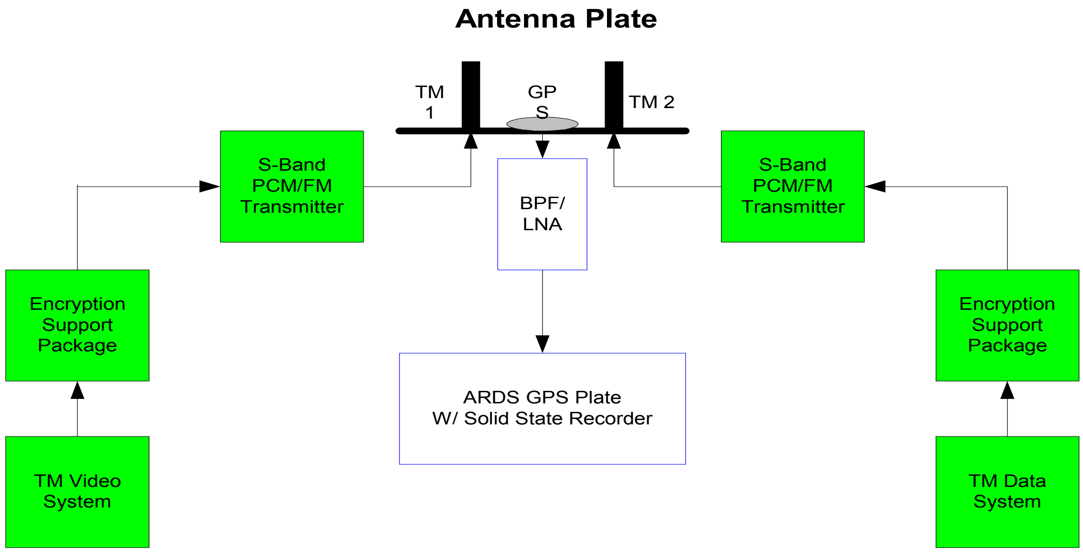

Figure 1. Instrumentation System Function Diagram

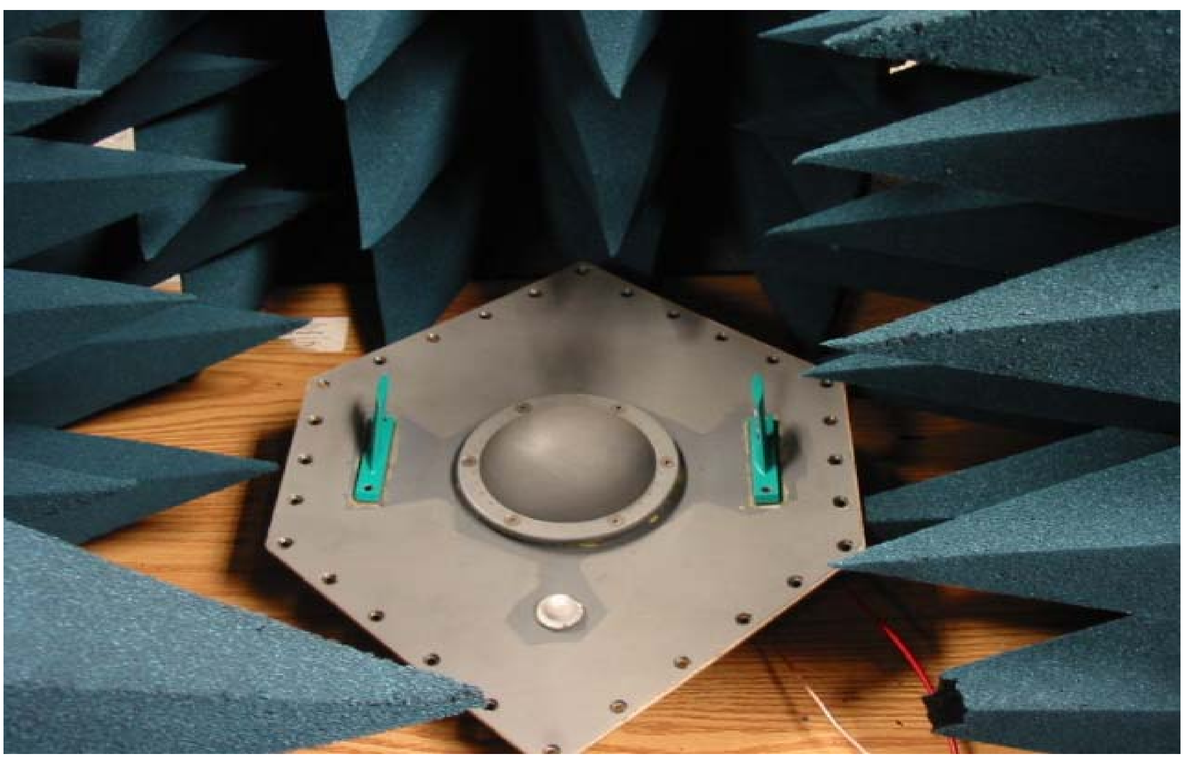

Figure 2. Instrumentation Antenna Plate

We initially attempted to install and test PCM/FM L-Band telemetry transmitters. Our lab tests and analysis seemed to indicate that it would be possible to use filters to eliminate and potential for interference but the on-aircraft testing proved otherwise. Our findings were that L-Band PCM/FM transmitters interfered with the GPS receive system even with filters installed. A cursory bench test of L-Band FQPSK transmitters revealed that they would likely be even worse due to their excess noise content being as much as 10 dB worse than the FM transmitters. At that point it became clear to us that S-Band FQPSK transmitters would be our best bet.

EQUIPMENT CHARACTERIZATION

To gain a better feel for the type and amount of interference we would be dealing with, we ran bench tests on selected items. The GPS system had previously been tested and was in use on a daily basis so no additional testing of it was deemed necessary. Manufacturers test data were available for the filters. The RF output characteristics of the FQPSK transmitter was the major unknown so we elected to focus our effort on testing them. We ran a series of tests to determine the spurious and excess noise levels of the transmitters. Figure 3 is a plot of the excess noise content of the transmitter in the GPS L1 band. In order to make this measurement, an amplifier was used to raise the noise above the spectrum analyzer noise floor. As can be seen in the plot, the output noise level increases as you drop lower in frequency and approach the GPS L1 frequency of 1575.42 MHz. To look for discrete spurs at the output, the transmitter was tuned in 1 MHz steps from lower band edge to upper band edge while monitoring the GPS bands for spurs. No problems were noted.

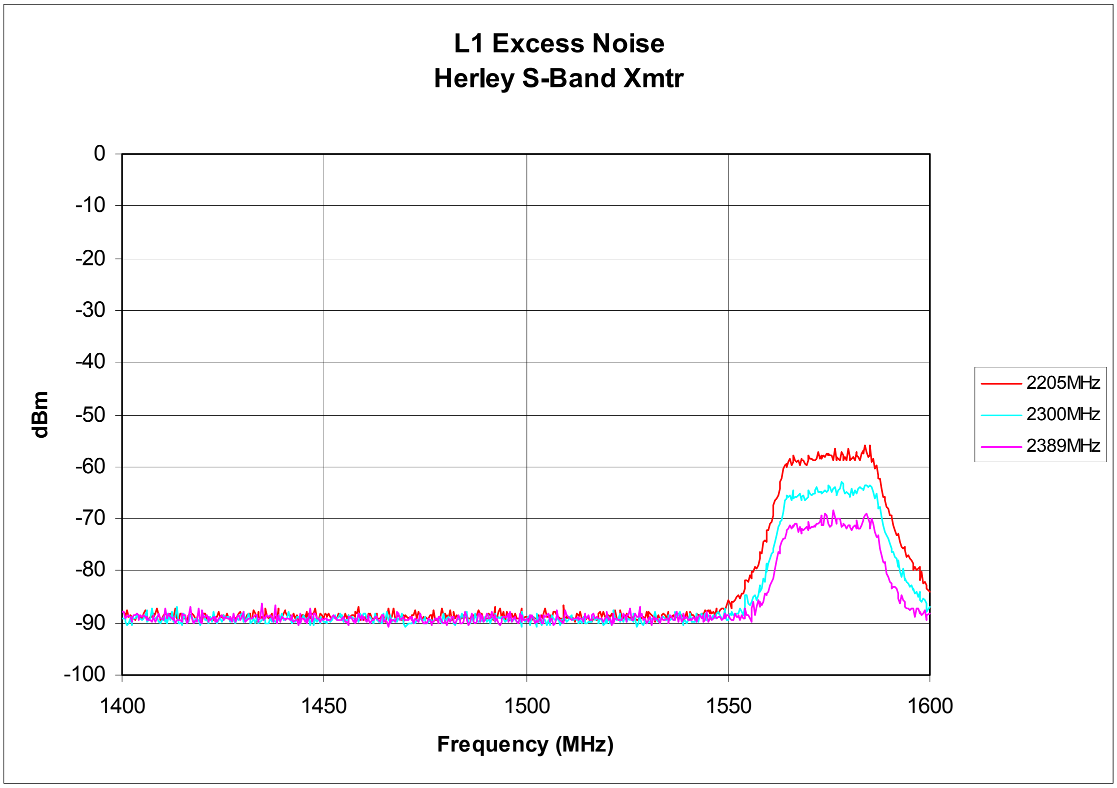

Figure 3. S-Band FQPSK Transmitter Excess Noise

LABORATORY MOCKUP

A laboratory mockup was created utilizing all of the equipment proposed for installation on the aircraft. Figure 4 depicts the configuration of equipment for the mockup. The same configuration was used later for open-air testing. The laboratory is equipped with a GPS antenna system which radiates GPS signals into the lab for GPS receiver checkout. Two S-Band FQPSK transmitters were setup and modulated with a bit error test set. Filters were placed in the transmitter outputs and at the GPS receiver input for some of the tests. The tests showed that the GPS receiver did appear to work okay without filters but the satellite carrier to noise levels dropped and fluctuated more frequently when the transmitters were keyed.

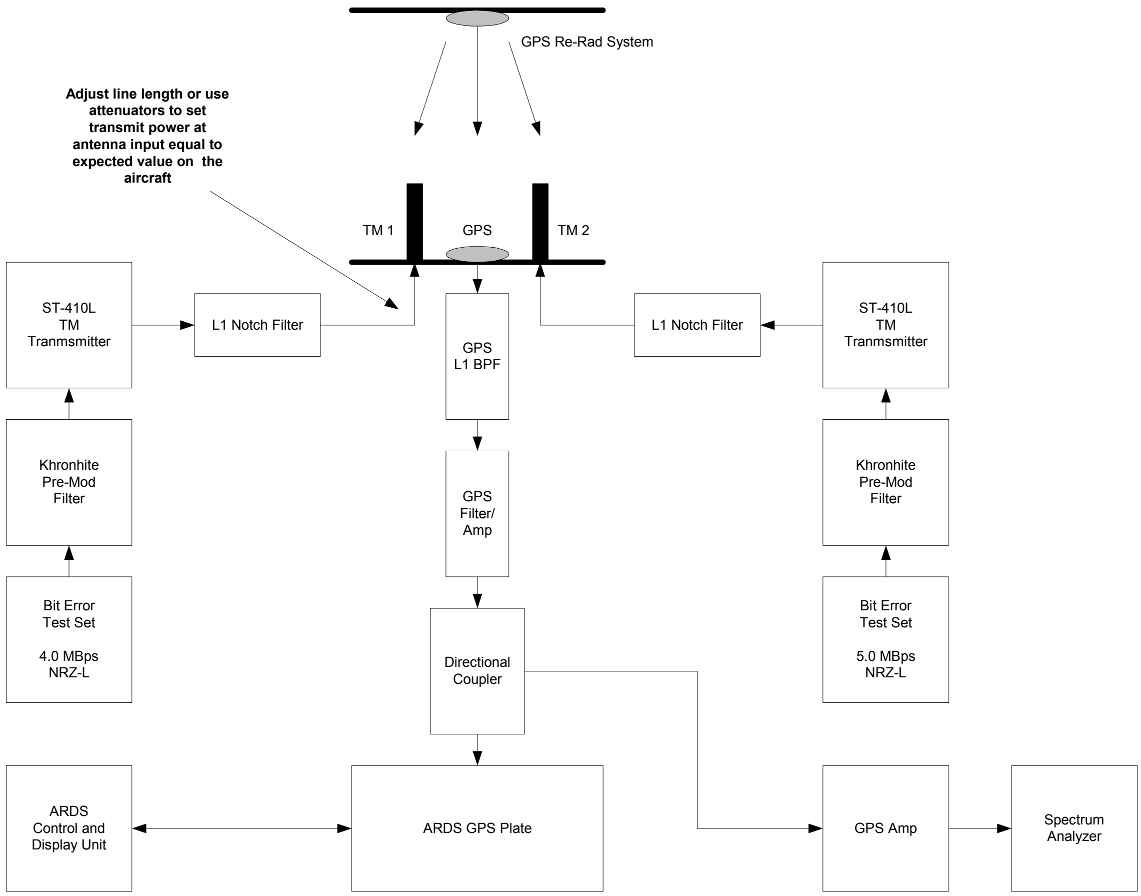

Figure 4. Laboratory Mock and Open-Air Test Configuration

OPEN-AIR TESTING

Although the results of the laboratory mockup tests were promising, we were somewhat skeptical of how well the GPS re-radiation system represented real-world signal levels. In order to alleviate those concerns, we elected to repeat the mockup test outdoors as a final test of our readiness to perform an on-aircraft test. Utilizing a mobile TM van, we brought all the equipment to a remote hill top site and ran a series of tests with generator power and the antenna panel placed on the roof. Figure 5 shows the equipment configuration in the TM van and Figure 6 shows how we mounted the antenna panel on the roof.

Figure 5. Telemetry and GPS Equipment in TM Van

Figure 6. Antenna Plate on TM Van Roof

Several tests where performed while GPS data were recorded on the ARDS HDIS solid state recorder. Short transmissions were made with each of the telemetry transmitters individually as well as both on at the same time. The RF spectrum was monitored for any sign of intermodulation problems stemming from the closely spaced antennas. Isolators were not used but were available in the event that intermodulation problems had been detected. Tests were performed with and without filters as well. As an added benefit, while we were testing the local telemetry site monitored our transmissions as a means for testing their own FQPSK receive capabilities. After completion of the test, the GPS data recorded were brought to the TSPI production office for evaluation. The GPS satellite carrier to noise ratio's were plotted before, during, and after each of the transmissions to look for any sign of RF interference affecting the GPS receiver. No significant problems were noted.

ON-AIRCRAFT TESTING

Add results of on-aircraft testing efforts here.

CONCLUSIONS

Conclusions to be written upon completion of on-aircraft ground tests. Pending Test completion.

REFERENCES

Add appropriate references here.

ACKNOWLEDGEMENTS

Add appropriate acknowledgements here.