NTPS AERONAUTCAL MOBILE TELEMETRY C BAND CONVERSION

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ABSTRACT

Due to the limited availability of L Band spectrum for non-government use, the National Test Pilot School (NTPS) has implemented a C Band airborne mobile telemetry (AMT) datalink system in order to continue to fulfill its mission to educate and train military and civilian flight test personnel. Instrumented aircraft were upgraded to support a PCM stream with higher resolution data and higher data rates required during performance & flying qualities and loads & flutter testing. This technology upgrade included a ground system that was both L and C Band capable and used a Smartronix Telemetry Receiver Processor to convert RF-to-IRIG Chapter 10 UDP packets for a direct input to an IADS® server in the NTPS control room. To achieve the similar performance to the legacy L Band datalink, a high gain, C Band antenna and low noise amplifier were installed as well as a new antenna rotator that allowed for higher precision movements and 360-degree continuous rotation in the pan axis. This paper will discuss the design analyses for and flight testing of the NTPS C Band datalink.

INTRODUCTION

Legacy NTPS Operations' use of aeronautical mobile telemetry in the L Band required de-confliction with users at Edwards Air Force Base. Although NTPS had been granted use of this spectrum on a non-interference basis, the process of requesting use of the L Band frequency was difficult and sorties were often rescheduled because another user had priority. As part of an NTPS technology upgrade, a new TM system was architected to not only break away from the existing frequency, but also to take advantage of present-day off-the-shelf technology.

Ground and flight evaluations of the C Band Telemetry system were performed using an AermacchiMB-326M Impala aircraft as the test platform. A build-up approach was taken to test and evaluate the C Band datalink that began with ground testing the individual components and subsystems. Functional checkouts, EMI/EMC testing, instrumentation calibrations and IADS® displays verification were performed; however, this paper will discuss only the system characterization flight testing performed at the NTPS in Mojave, California, during November of 2016.

SYSTEM DESCRIPTION

The C Band Telemetry system comprised of both airborne and ground components. The operating frequency was fixed at 5.1 GHz. The modulation type was PCM/FM with a bit rate of 250 Kbps. The total RF transmit power was 20 Watts (+43 dBm).

Airborne Components
The airborne components included a Nginuity signal conditioner and Data Acquisition System (DAS), a Quasonix C Band transmitter, a 50/50 RF splitter, and 2 omni-directional blade antennas, as shown in Figure 1. The DAS digitized instrumentation sensor outputs and sent PCM telemetry frames to the transmitter over a 4-wire (data and clock) RS-422 serial interface. The transmitter randomized the PCM data and modulated it using a carrier frequency of 5.1 GHz. The RF output of the transmitter was then divided by a 50/50 splitter and fed to two aircraft antennas, one located on the bottom fuselage and one located on the top side of the fuselage.

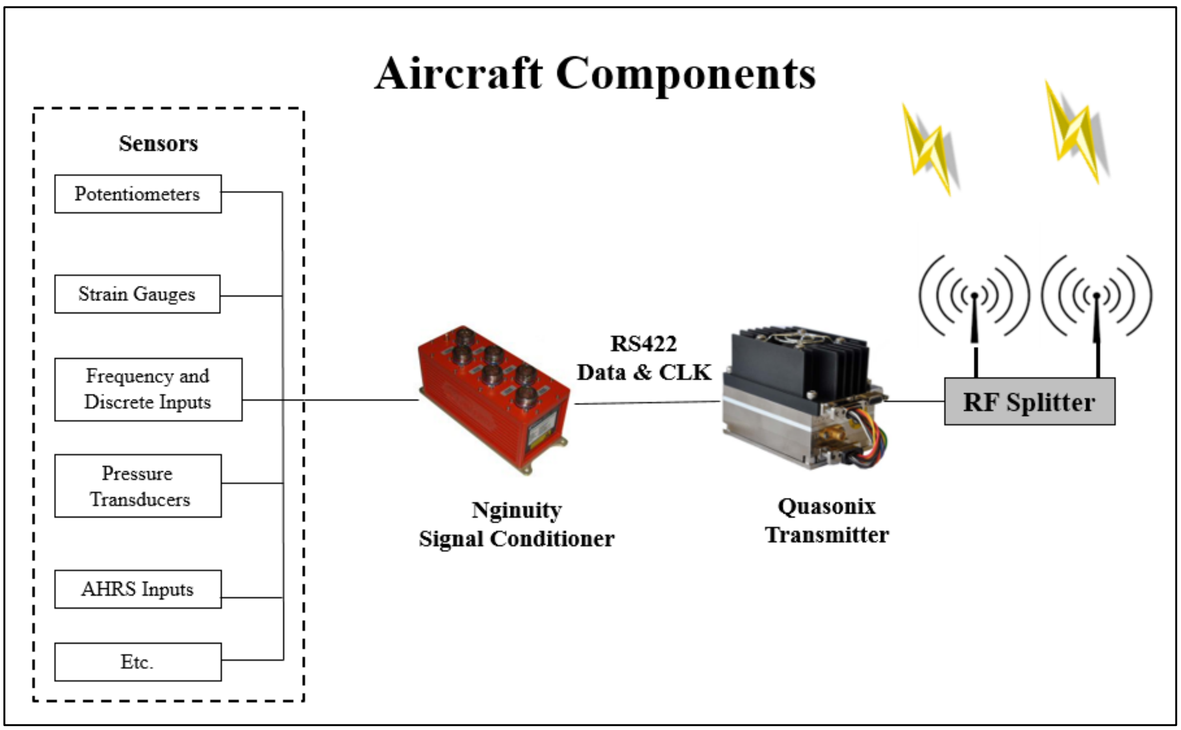

Figure 1 Aircraft Components.

Ground Components
The ground components included a high-gain parabolic dish antenna, a Low Noise Amplifier (LNA), a 36-inch coxial cable, a Moog antenna rotator, a 50-ft low-loss coaxial cable, and a two-channel, dual-band Smartronix receiver and telemetry processor. The downlinked signal was received by the rooftop antenna and passed through the rotary joint of the antenna rotator and coaxial cabling into the building and eventually to the receiver. The receiver performed the RF-to-IF down-conversion and demodulated the signal to TTL-level data and clock inputs. The TTL signals were fed to a PCM module within the receiver for processing into IRIG Chapter 10 UDP packets. These packets were broadcasted onto the NTPS network in which an IADS®™ server

was configured to decommutate and pass IADS® data to client computers in the TM Control Room. Figure 2 shows the ground components setup.

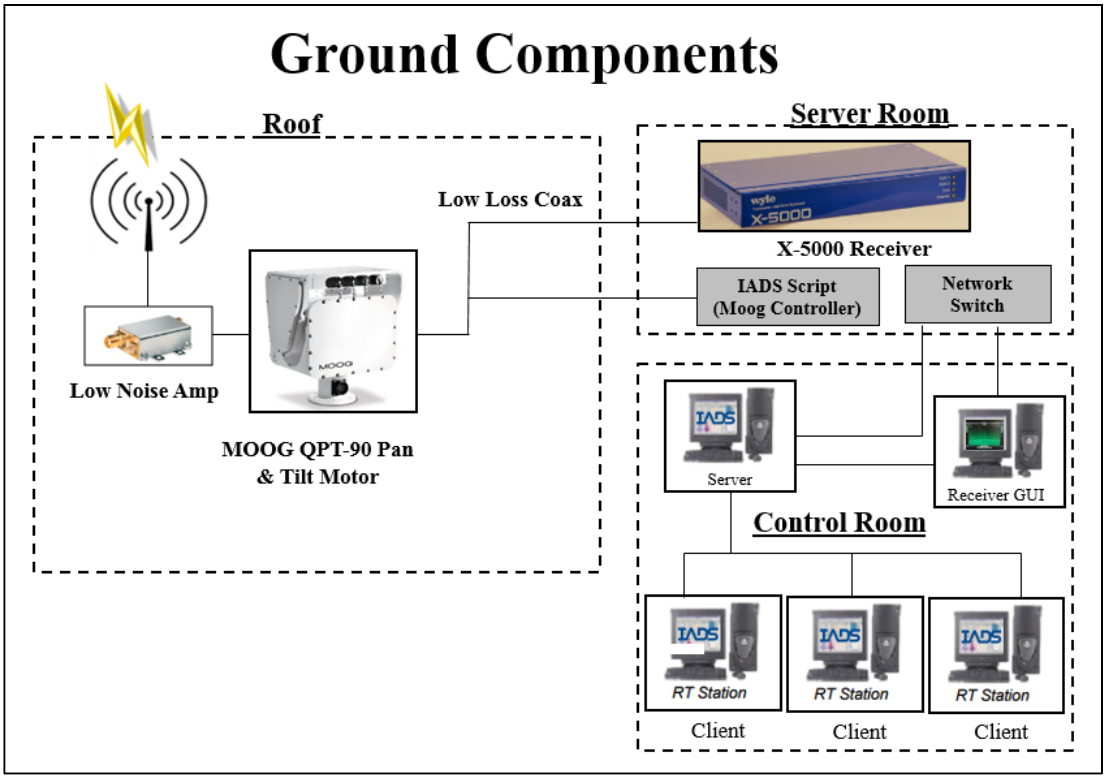

Figure 2 Ground Components.

LINK MARGIN AND NOISE FIGURE ANALYSES

Noise figure and link margin analyses were completed using guidance from [1] and are presented in Table 1 and Table 2, respectively. Due to a limitation in the RF test equipment available for measurements, values used in the analyses were obtained from component datasheets. An operating range of 40 Nmi (a limitation of the experimental aeronautical mobile telemetry license) was used in the maximum range analysis and a margin of 10.9 dB was calculated. An operating range of 150 ft (the shortest distance expected between the aircraft and the ground station) was used in the minimum range analysis and a received signal strength at the receiver of -15 dBm was calculated. The purpose of minimum range calculations was to ensure avoidance of receiver saturation and/or damage.

Table 1 System Noise Figure Analysis.

	LNA	Short Coax	Rotator	Long Coax	Receiver
Component Gain (dB)	24.0	-1.0	-1.8	-10.0	variable
Component Noise Figure (dB)	2.0	1.0	1.8	10.0	6.0
Noise Factor contribution by stage (absolute)	1.6	0.0	0.0	0.1	0.2
				System Noise Factor (absolute)	**1.9**
				System Noise Figure (dB)	**2.7**

Table 2 Link Margin Analysis.

	TRANSMIT PATH		
1	Frequency	5.1	GHz
2	Power TX	43.5	dBm
3	RF Splitter	3.4	dB
4	Cable Loss	0.5	dB
5	TX Antenna Gain	0.0	dBi
6	EIRP Max.	39.6	dBm
	RECEIVE PATH		
7	Range	40.000	Nmi
8	Atmostpheric Atten	144.0	dB
9	Scattering/Reflections Loss	10.0	dB
10	RX Antenna Gain	26.8	dBi
11	Circular Polarization Loss	3.0	dB
12	Low Noise Amplifier	24.0	dB
13	Cable 1 Loss	1.0	dB
14	Rotator Pass Thru Loss	1.8	dB
15	Cable 2 Loss	10.0	dB
16	TOTAL LOSS	119.0	dBm
17	Power at RCVR (Line 6 - Line 16)	-79.4	dBm
	SYSTEM TOTALS		
18	RCVR Sensitivity @ 1 Mbps***	-93.0	dBm
19	System Noise Figure	2.7	dB
20	**Link Margin (Line 18+Line19-Line17)**	**10.9**	**dB**
	***Sensitivity value of the RCVR was provided by vendor. ***Actual bit rate implemented in system was 250 Kbps.		

SYSTEM CHARACTERIZATION FLIGHT TEST

General

The objectives of the system characterization flight were to verify a maximum range of greater than 40 Nmi and to verify a robust telemetry datalink at different aircraft aspects relative to the ground station and aircraft attitudes. Telemetered data processed by IADS® as well as receiver RF signal strength and spectrum data were displayed in real-time and were also recorded for post-flight analysis.

Maximum Range Testing

A maximum range test was performed to determine if the datalink could operate out to a maximum range of 40 Nmi (as granted by the FCC AMT License). The aircraft was flown in the north-northeast direction from Mojave Air and Space Port (KMHV) at 12,500 FT MSL with a tail-on aspect. (A total loss of link was defined as the receiver losing lock for at least a 3-second duration.) No intermittent dropouts were observed during the entire leg outbound. The aircraft was vectored back to the southwest once beyond maximum range. A screenshot of the IADS® display and spectrum at the receiver is shown in Figure 3. The greatest range achieved before turning inbound was 43.21 Nmi and no loss of signal was observed. The signal strength measured at this range was -82 dBm, which agreed to within 2 dBm of the link analysis. The maximum range requirement of 40 Nmi was met therefore allowing school sorties to be flown within the NTPS operating working areas with reliable telemetry.

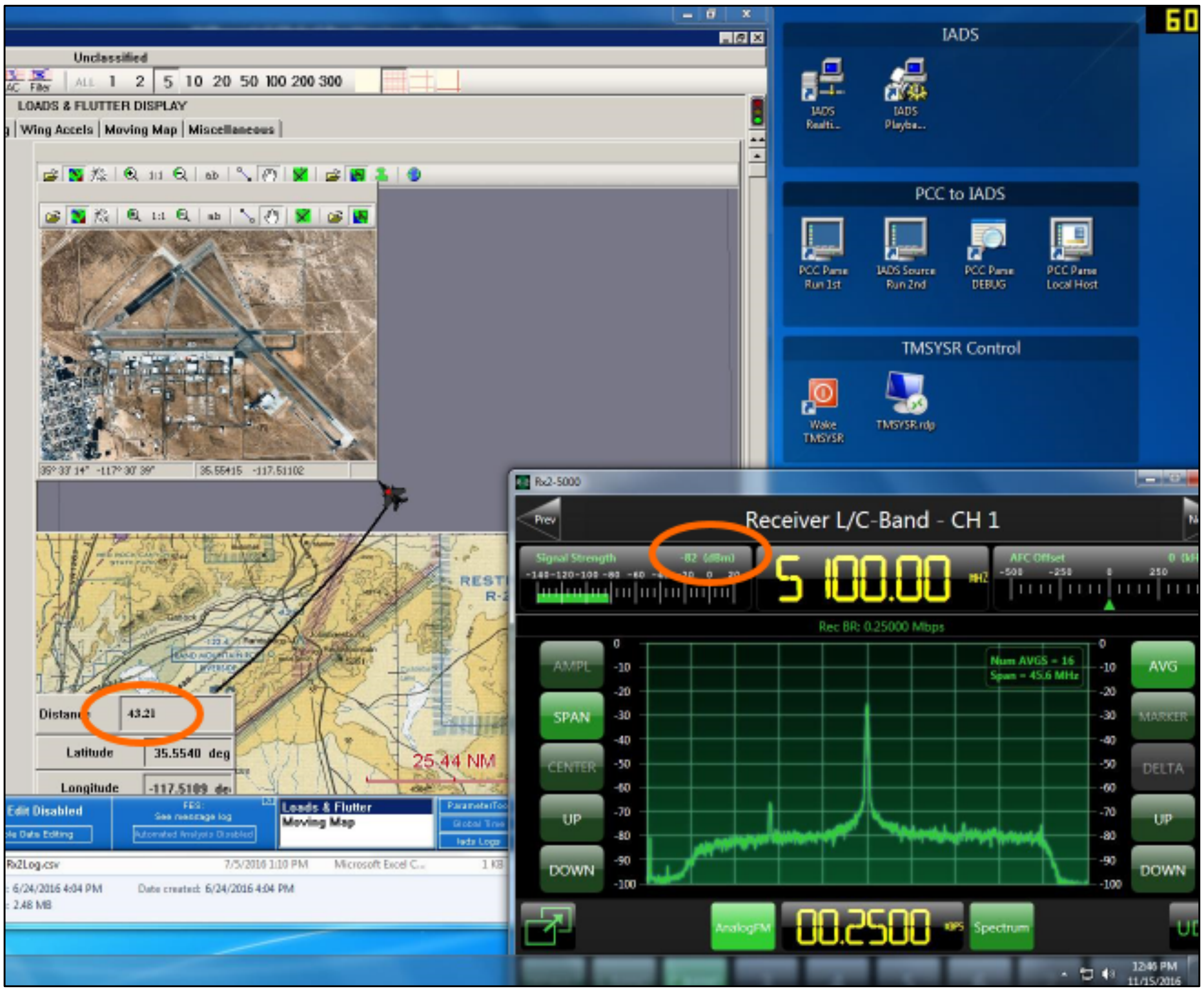

Figure 3 Maximum Range Test Screen Capture.

Aspect Testing

RF performance of the datalink at different aircraft aspects was verified. One clockwise and one counter clockwise square ground track pattern were flown at 16,500 ft MSL at a range of approximately 15 Nmi. The counter clockwise track is shown in Figure 4. The range of signal strengths measured and the percentage of time during the leg that telemetry dropouts occurred are summarized in Table 3.

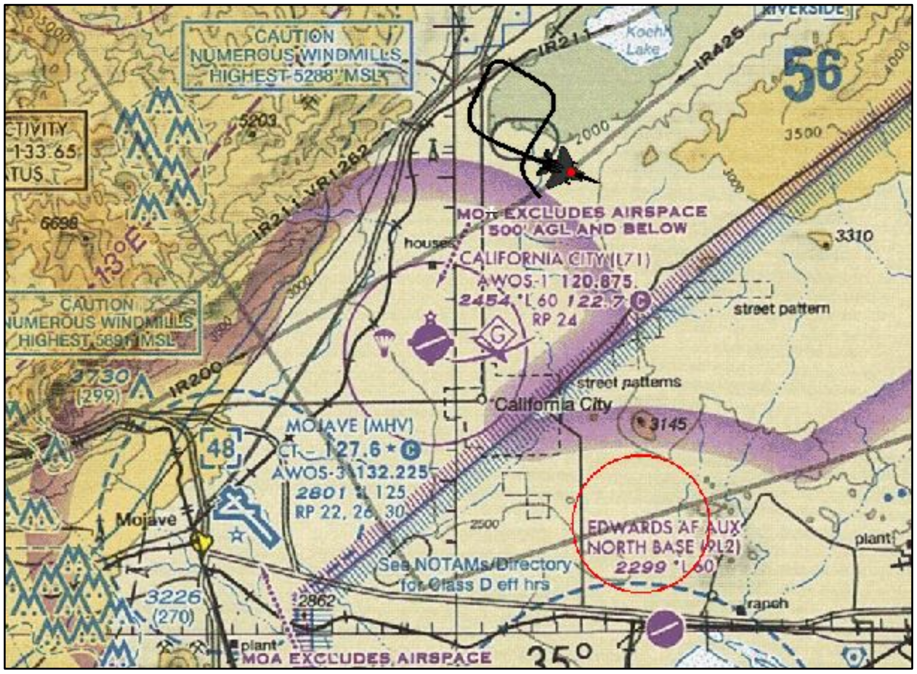

Figure 4 Ground Track Pattern during Aspect Testing.

Table 3 RF Performance during Aspect Testing.

Direction	Aspect	RF Signal Strength	% of Time w/ Dropouts
Clockwise	Tail On	-79 dBm to -70 dBm	No Dropouts
	Right Wing	-93 dBm to -71 dBm	No Dropouts
	Nose On	-87 dBm to -80 dBm	No Dropouts
	Left Wing	-83 dBm to -74 dBm	No Dropouts
Counter-clockwise	Tail On	-83 dBm to -68 dBm	No Dropouts
	Right Wing	-89 dBm to -79 dBm	No Dropouts
	Nose On	-96 dBm to -80 dBm	No Dropouts
	Left Wing	-98 dBm to -83 dBm	No Dropouts

For both directions the tail-on aspect showed the best performance and the use of 2 antennas of equal power output operating simultaneously did not appear to have any adverse effects, e.g. destructive interference. Though the signal strength varied, the receiver never exhibited a dropout or loss of lock. With the new system, a sortie which involves flying the aircraft at different aspects relative to the ground antenna will experience high telemetry reliability and dropouts will be infrequent.

Roll Attitude Performance

The RF performance at various varying roll attitudes was verified. While inbound on a nose-on aspect and at an altitude of 12,500 ft MSL and range of approximately 30 Nmi, wing-rocks (bank variations) were performed. Bank angles during the maneuvering varied between $\pm 60^0$ and were flown to a roll rate of less than 10 ^{0}/sec (or approximately ½ lateral stick deflection). Small variations in heading and yaw were permitted. The ground track and spectrum at the receiver are shown in Figure 5. No RF dropouts or loss of lock were observed while maneuvering.

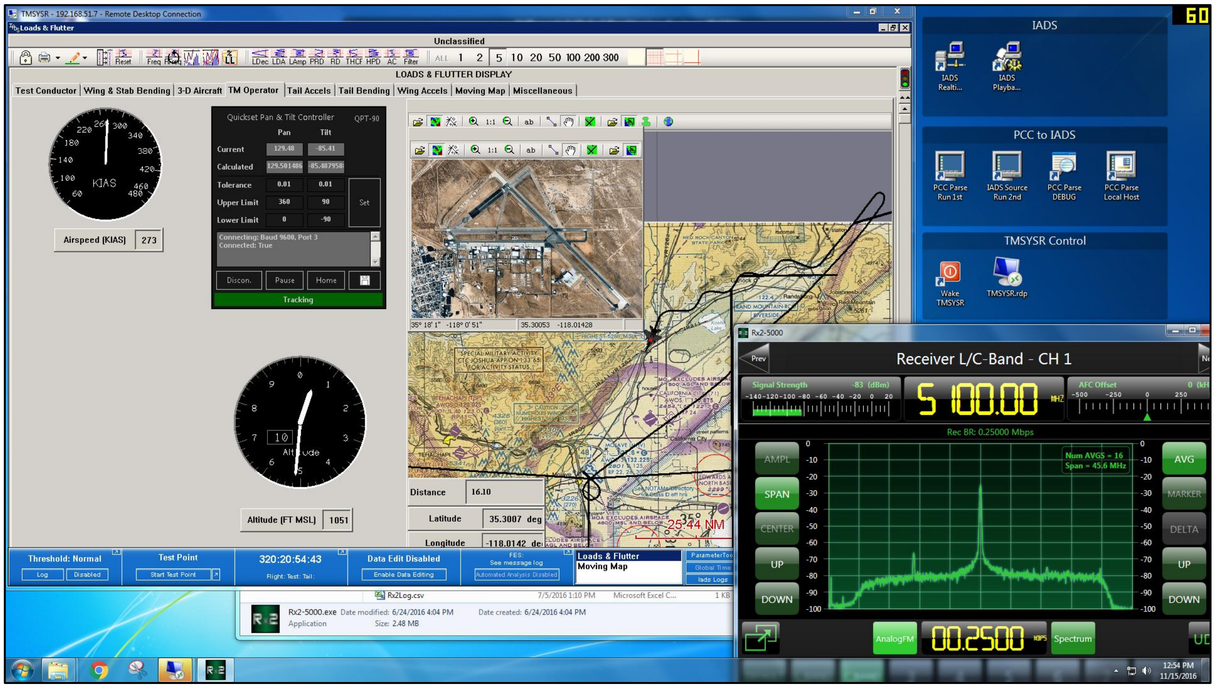

Figure 5 Roll Attitude Performance Testing.

Pitch Attitude Performance

Similar to roll attitude testing, the RF performance at varying pitch attitudes was verified. Pitch attitude evaluation maneuvers were performed by continuously varying the pitch attitude ($\pm 45^0$) of the aircraft in a sinusoidal/roller coaster pattern for 3 cycles. The wings remained level during the pull-ups and pushovers, and the pitch rate did not exceed 3 ^{0}/sec. No RF dropouts were observed while maneuvering.

CONCLUSIONS

The system characterization flight test results presented above showed evidence of a robust datalink. The maximum range was greater than 40 Nmi, a limit hindered only by the FCC experimental mobile telemetry license. The system performed reliably with no dropouts as aircraft aspect, attitude, and range from the ground station was varied. The NTPS AMT C Band conversion will allow for a continued telemetry capability in order to support the school's mission of flight test training and education.

REFERENCES

[1] D. M. Pozar, *Microwave and RF Design of Wireless Systems*, John Wiley & Sons, Hoboken N.J., 2001.