HIGH ALTITUDE TRANSMITTER FLIGHT TESTING

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ABSTRACT

This paper describes a high altitude experimental flight test platform developed by the University of Kansas (KU) and the National Nuclear Security Administration's Kansas City Plant (NNSA's Kansas City Plant) for high altitude payload flight testing. This platform is called the Kansas University Balloon Experiment Satellite (KUBESat). The paper describes the flight test platform and experimental flight test results captured at Fort Riley, KS from characterization of the KCP developed Distributed Transmitter (DTX)[1].

KEYWORDS

High Altitude Flight Testing, Flexible Transmitter Characterization, Balloon Flight Testing, Long Range Link Testing, Near Space Flight Testing

INTRODUCTION

High Altitude Flight Testing Applications

Several applications for high altitude flight testing platforms include: 1) Near space payload flight testing, 2) Low cost, large area coverage infrastructure, 3) commercial and military remote sensing, 4) Earth atmospheric and interplanetary atmospheric and surface research, 5) Long range data acquisition infrastructure.

University of Kansas Space Program

The KU space program started officially in June 2002 with the conceptual design of its first satellite: the Kansas Universities Technology Evaluation Satelite-1, the *Pathfinder*. Although Kansas universities have been involved for many years in space research (e.g., Space Shuttle "Getaway Special" payload developed by KU, various instruments developed by KU and other universities that have been flown on satellites, and the space-based activities of the Kansas Applied Remote Sensing Program), until the KUTESat Program there has been no project in the state to develop and fly an entire satellite. However, several universities, including KU, have ongoing research in electronics and wireless communications that would be applicable to satellites. The only existing research currently in the state for the development of satellites is the KUTESat *Pathfinder* project.

The program can count on numerous laboratories and shops located at the University of Kansas main campus in Lawrence. With professors and lab technicians as advisors, the students are

[1] U.S. Patent Application 10/271,459, filed 10/15/02.

encouraged to manufacture in-house as much as possible. Mechanical and structural labs are located in Learned Hall and in the KU hangars at the Lawrence Municipal Airport, while electronic and computer science labs are located in Nichols Hall and Eaton Hall.
The final objective of the Space Program is to establish a space industry in Kansas building on two existing strengths of the State of Kansas, aerospace/aviation and information technology/communications, to create a new technology area. The accomplishment of the KUTESat Program will allow the state of Kansas to gain national recognition and participate in future space projects.

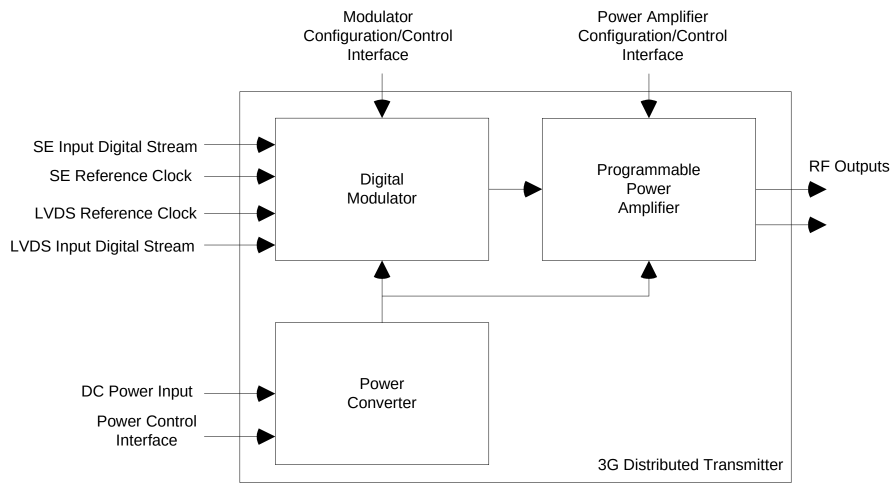
NNSA’s Kansas City Plant
The NNSA‘s Kansas City Plant is a Department of Energy-owned facility managed by Honeywell Federal Manufacturing & Technologies (FM&T)[2]. Since 1949, this facility has procured or manufactured over 85% of the non-nuclear components and materials required for the nuclear stockpile. With 3.2 million square feet, and a broad range of electronic, mechanical, and material design, development, fabrication, and testing capabilities, the Kansas City Plant is a one-stop national product realization asset. The Kansas City Plant is a distinguished member of the nuclear weapons complex and a partner with the National Laboratories in the design, development, manufacturing, and testing of our nation’s defense systems.

Advanced Telemetry Technology Development
The NNSA’s Kansas City Plant Advanced Telemetry Technology Development Program has supported the JTA and developmental telemetry weapons evaluation programs for over four decades with remote data acquisition telemetry systems. In addition to development and manufacturing of JTA nuclear weapons evaluation telemetry systems, they have supported the NNSA's weapons evaluation program with flight test technology including transducer, sensor, electro-optical, analog, digital, and microwave signal processing, control, data processing, transmitter, receiver, and antenna developments. These developments have been with core national defense customers from multi-million dollar IR&D programs directed to support forward looking advanced technology deliverables.

Distributed Transmitter Description
The Distributed Transmitter (DTX) is a flexible, modular, compact, multi-mode data link transmitter. It includes features such as: 1) Flexible preflight configuration of modulation, data rate, RF output power, carrier frequency, bandwidth, and power efficiency, 2) agile in-flight control of modulation, data rate, RF output power, carrier frequency, and bandwidth, and 3) compact modular physical design.

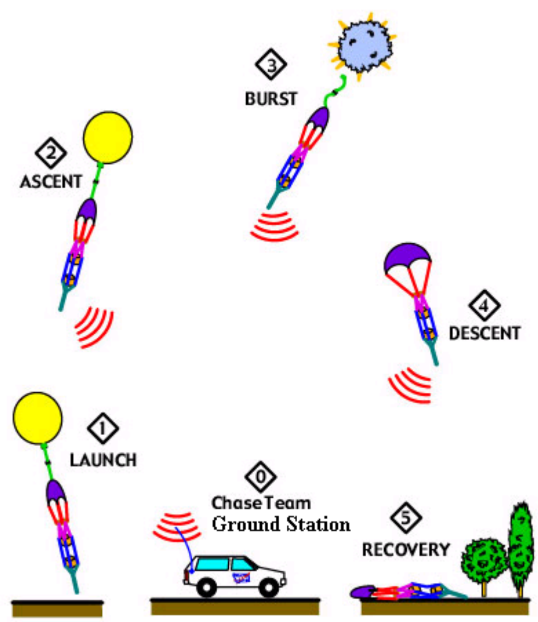
[2] Operated for the United States Department of Energy under Contract No. DE-ACO4-01AL66850

The Distributed Telemetry Transmitter (DTX) developed by Honeywell engineers at the Kansas City Plant is a modular data communication microwave transmitter. It consists of three separate components—a digital modulator; a power amplifier; and a power converter. Based on user needs, the DTXR system is implemented by using from one to three hardware modules. The power converter module is optional if the required DTXR power can be integrated into the application system power supply. Therefore, the transmitter could comprise of the digital modulator module and a single amplifier module if the power converter module was not required. This modularity provides significant flexibility. Functional blocks can be distributed or co-located as required by the application. Individual enclosures can be stacked, placed end-to-end, side-by-side, or a combination of these configurations. Interconnections between the modules are standardized so that power and signals can be passed between them. The DTXR System incorporates modular digital and microwave technology so that data rates, carrier frequency, bandwidth, efficiency, and output power can be customized for a multitude of applications. Through the configuration interface, it offers off-the-shelf configuration of carrier frequency, data rates, RF output power/efficiency, modulation/spectral efficiency, and bandwidth containment components within a small, flexible mechanical configuration. An operational control interface enables real-time, asynchronous control of modulation/spectral efficiency, carrier frequency, data rate, bandwidth, and RF power. Characterizing the DTX is important to establish a performance baseline prior to troubleshooting data link problems from a dynamic flight test environment.



KUBESat System Description

The KUBESat platform provides a functional platform to characterize the DTX in a long range field test environment. The KUBESat provides command, control, and communication (C3) interfaces (see appendix) in addition to a lighter than air lift system. The C3 interfaces enable the DTX to be reconfigured during flight and down link of test data to a ground station in order to achieve the goals of the test plan. The KUBESat operational plan prescribes a flight that begins within the boundaries of Ft. Riley, KS and ends approximately 2 hrs and 80km away after reaching a peak altitude of 30 km.



The KUBESat project, originated in late 2002, is a cooperative effort between the Aerospace Engineering and Electrical Engineering departments at the University of Kansas, the Information Technology and Telecommunications Center (ITTC), and at the NNSA's Kansas City Plant. The primary goal of this program is to design, build, test, and operate a satellite-like vehicle, commonly called a BalloonSat, containing one or more experiments and launched on a weather balloon. The BalloonSat launch vehicle and recovery system, developed to support the KUBESat program is the KU High Altitude Balloon System (KU HABS). The HABS consists of a weather balloon for ascent, a parachute for descent, and an instrument module (HABS BalloonSat). The module contains a GPS receiver, a HAM transceiver for communication with the ground, camera, environmental sensors, and additional payloads. The KUBESat becomes a payload to the HABS, and serves to support C3 interfaces for the DTX payload.

The primary purpose of the first KUBESat mission, KUBESat-1, is to characterize the DTX and provide a test platform for additional data link developments. A secondary objective of the program is to help with the development of Kansas Universities' Technology Evaluation Satellite (KUTESat) projects. The KU HABS and KUBESat programs have actively involved industry and education outreach in the design and development phase to create the bases for future collaboration.

KUBESAT DTX FLIGHT TEST PLAN

The objective of this flight test is long range performance characterization of the 3G version of the DTX. Determination of modulator and power amplifier function in a field test environment is paramount. During the flight DTX configuration will be varied in several dimensions with predictable effects on power, spectrum, and BER. As these parameters are changed, empirical measurements of link parameters will enable characterization of performance.

Modulator parameters of interest include modulation type, data rate, and data filtering. Power amplifier parameters of interest include output power. Measurements of received power, BER, RF Spectrum, and data stream will be utilized to score the performance of the transmitter. BER measurements shall be based on a repeating 32 bit sequence that correlates with BER equipment supplied in the ground station. RF spectrum shall be measured using a Spectrum analyzer that can determine 99% power level. The data stream shall be recorded on the output of the data decommutator. The received power shall be measured with an approved RF power meter.

An experimental test schedule has been created that investigates effects of parameter variation for both the modulator and the power amplifier. Thirty two cases shall be demonstrated at eight locations during the flight test environment at each of the indicated flight profile locations (see diagram). At a minimum, the following data shall be recorded at each flight test profile test point: 1) received power, 2) BER, 3) multiple frames of data stream, and 4) Spectrum plots.

Data Analysis/Reporting

The following data analysis shall be conducted: 1) Measured received power shall be compared against expected received power and deviations of 3dB shall be recorded, 2) Measured BER shall be compared to expected BER and deviations of higher than 1E-6 shall be recorded, 3) Spectrum plots of RF spectrum shall be recorded for each test point, 4) A minimum of one complete data frame shall be recorded at each test point. All recorded data shall be organized into a final test report.

Flight Profile

The flight profile is shown below. The balloon will achieve altitudes of approximately 30 Km and will travel a maximum of 80Km during the 2.0 hour flight. Anticipated look ranges are expected between 12 and 70 km. Expected received power are between -84 and -107 dBm assuming linear flight location, frequency of 2250 MHz, system losses of 6 dB, transmit antenna gain of 1dB, and receiver antenna gain of 10 dB, vertical polarized antennas, and transmit powers between 1 and 10W.

ANTICIPATED FLIGHT TEST RESULTS

Expected results will vary according to general relationships as follows:

- Transmit power decreases, receiver power decreases, everything else the same
- Range increases, receiver power decreases, everything else the same
- Receiver power decreases, BER increases, everything else the same
- Data rate increases, energy per pit decreases, BER increases, everything else the same
- Modulation type changes from FSK to SOQPSK, BER decreases, everything else the same
- FSK modulation increases bandwidth, everything else the same
- SOQPSK decreases bandwidth, everything else the same

During the test sequence, verify that that general expected relationships are observed in the measured data. Compare and report any deviations between expected and measured BER.

ACTUAL FLIGHT TEST RESULTS

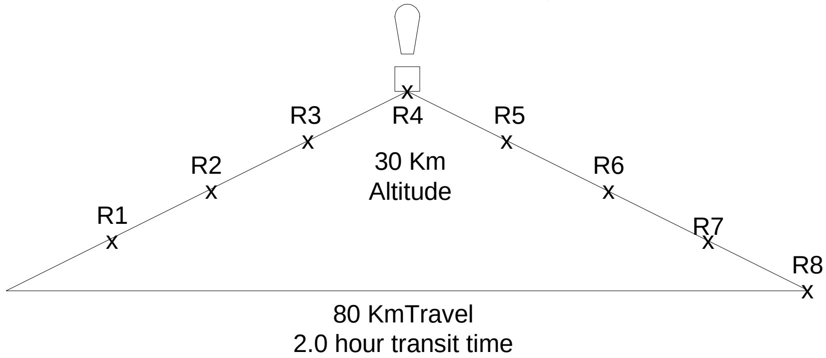
KUBESat flight testing is scheduled for 9/04. Final Results were not available when this paper was submitted for publication. However, the flight test data will be presented at the 2004 ITC conference and final conclusions will be presented at the conference.

CONCLUSION

Final conclusions will not be made available until the ITC conference. An analysis between empirical and analytical results will be provided after the flight testing is completed in 9/04.

ACKNOWLEDGEMENTS

I would like to thank the engineering staff of the NNSA's Kansas City Plant Advanced Engineering Department for their investments in design consultation, design reviews, system integration, and system testing. Particularly, Troy Kaeb, Dean Oliver, and Daric Laughlin. I would also like to thank NNSA's Kansas City Plant management for investment support and authorization to invest in the KUBESat program, namely Bill Ross and Dan Meservey. I would



also like to thank the University of Kansas faculty and staff for their leadership and expertise which made the KUBESat system come to life, primarily Dr. Trevor Sorensen, Dr. Chris Allen, and Dr. Glenn Prescott. And finally I would like to thank the KU graduate engineering students that invested in the design, development, and testing of the KUBESat system, namely Marco Villa, Nikhil Paruchuri, and the other KU student team members.

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APPENDIX

BalloonSat/KUBESat Data and Command Diagram

Updated: March 7, 2003