DYNAMIC TRACKING PHASED ARRAY DATA LINKS

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ABSTRACT

This paper describes a flexible telemetry data link developed by National Nuclear Safety Administration's Kansas City Plant (NNSA-KCP) and the University of Kansas (KU) in support of NNSA's Remote Sensing Laboratory (NNSA-RSL) located at the Nevada Test Site. This data link is based on a beam steerable phased array antenna (PAA). The paper describes the PAA and the Airborne Measurement System (AMS) application requiring signal source tracking. It highlights flight test data collected during recent flight testing on the Nevada Test Site for the AMS.

KEYWORDS

Tracking Data Links, Phased Array Data Links, Beam Steering Antennas

INTRODUCTION

Flexible Data Links Applications

There are several important applications for dynamic steerable data links including: 1) scanning remote sensors, 2) low probability of detection, 3) tracking data links, 4) dynamically directed data links.

University of Kansas Radar Lab Description

Since 1964, the Radar Systems and Remote Sensing Laboratory (RSL) has been educating engineers and future leaders in the area of radars, microwaves, communications, and remote sensing techniques for the 21st Century. The RSL applies microwave remote sensing to improve our understanding of the ocean, atmosphere, sea ice, polar ice, vegetation, snow, soil moisture, and subsurface features. Activities include sensor development, data collection, analysis and modeling, and data dissemination. Recent projects focusing on polar ice sheet characterization support global climate change and sea-level rise studies as well as interplanetary missions. RSL has earned an international reputation and has been supported by NASA, the National Science Foundation, the Jet Propulsion Laboratory, the US Army, and the Office of Naval Research. The RSL has several focus areas including: 1) Ice-sounding radar, 2) Ground-penetrating radar, 3) Oceanographic radar, 4) Scanning radiometer system analysis, 5) Synthetic-aperture radar system analysis, 6) RF and microwave engineering, and 7) Radar data analysis. Project areas include: 1) Ice sounding radar for mapping polar ice-sheet thickness, glacier profiles, and internal layering features in support of global climate change research, 2) Ground-penetrating radar for detection of anti-personnel land mines and detecting and mapping subsurface containments, 3) Oceanographic sensing for mapping surface wind fields and rain events for climate models and surface slope for oceanographic research, 4) Synthetic aperture radar systems development for space based systems, data processing techniques, and image analysis techniques, 5) RF and microwave engineering for development of novel RF signal generation and signal processing systems, custom antenna systems, and data collection systems for remote sensing applications, and 6) Radar data analysis for reduction of raw radar signal data to extract information on target characteristics. The RSL is equipped with state of the art electronic equipment that enables support for each of the project areas.

NNSA's Kansas City Plant

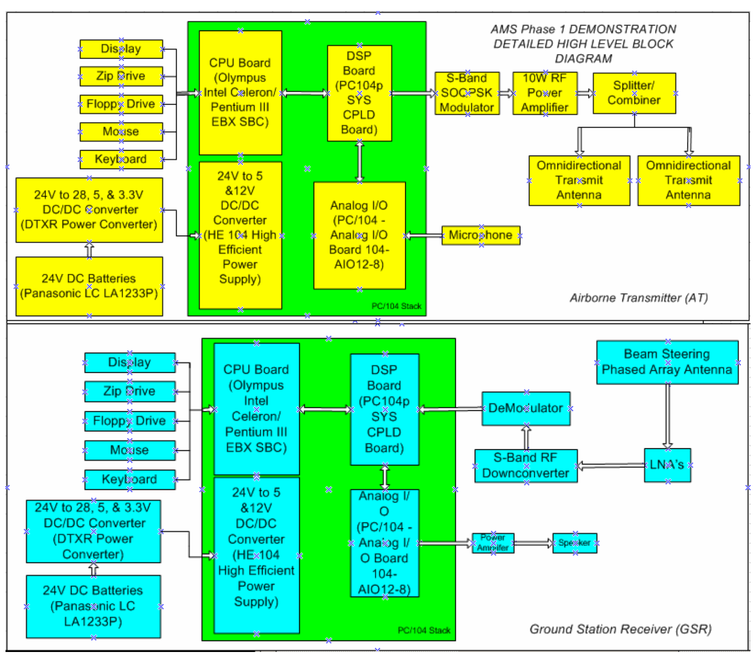
The NNSA's Kansas City Plant is a Department of Energy-owned facility managed by Honeywell Federal Manufacturing & Technologies (FM&T)[1]. Since 1949, this facility has procured or manufactured over 85% of the non-nuclear components and materials required for the nuclear stockpile. With 3.2 million square 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 4 decades with remote data acquisition telemetry systems. In addition to development and manufacturing of Joint Test Assembly (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.

AMS System Description

The AMS is under development at NNSA-KCP to support NNSA-RSL requirements. An overall capability will be developed over multiple years with a baseline demonstration to be completed in FY04. The first demonstration of this capability is to produce a simplex, high rate, long range, downlink of sensor and voice data from an airborne platform to a small, man transportable, ground station. To achieve this goal, the AMS has two primary subsystems. The first is an Airborne Transmitter (AT) that provides a capability to interface with



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

users, signal sources, and sensors on an airborne platform, and links them across a long range, wideband, wireless channel. The second subsystem is a portable Ground Station Receiver (GSR) and provides receiving assets for the wireless channel with interfaces to users, data processing, and storage. These two subsystems together provide an airborne data transmitter and a ground receiver communication system with potentially 30+ miles of range. With isotropic antennas on the airborne platform, and the PAA on the GSR, the system enables automatic tracking and download of sensor and voice data within a very large area. The PAA digital controller enables automatic search and tracking modes of the AT as it moves through the area of interest without large dish or large tracking mechanisms. Because the wireless interface is configurable in terms of modulation, frequency, power, bandwidth, and spatial beam pointing, a number of applications can be implemented. Both the AT and the GSR provide user interfaces and application execution within an PC operation system environment. This enables system configuration and control of the wireless link, and also system function. The wireless interface is based upon configurable transmit and receiver functions developed at NNSA-Kansas City Plant. A complex programmable logic device (CPLD) provides an interface between the PC environment and the wireless interface. Integrated battery and power systems provide independent field operation for up to 4 hours. Both the AT and the GSR will be iteratively developed at the Kansas City Plant over the next couple of years. Each are anticipated to be less than 1.5 cu ft and less than 75 lbs.

Phased Array Antenna Description

The eight element antenna array design has a nominally fixed radiation pattern beamwidth both in elevation and azimuth and has been designed to provide electronic steering in azimuth. The eight individual array elements exhibit a center frequency of 2.35 GHz, with a -3dB bandwidth of 100 MHz. Each element is comprised of a planar microstrip antenna combined with active and passive circuitry including two stages of RF bandpass filtering, low noise RF amplifiers, voltage variable phase shifters, and a voltage variable attenuator. The eight array elements are coupled together via two 4-port RF power combiners and a 180° hybrid coupler. Sum and Delta outputs from the hybrid coupler are applied to an analog RF Signal Processor, which in turn generates scaled DC voltage levels that drive the voltage variable phase shifter circuitry on each array element. As shown in Figure 1, the RF Signal Processor has two DC voltage level outputs, the **Sum level** and **Delta level,** which indicate relative Sum and Delta channel RF signal power levels received by the antenna. The **Digital**

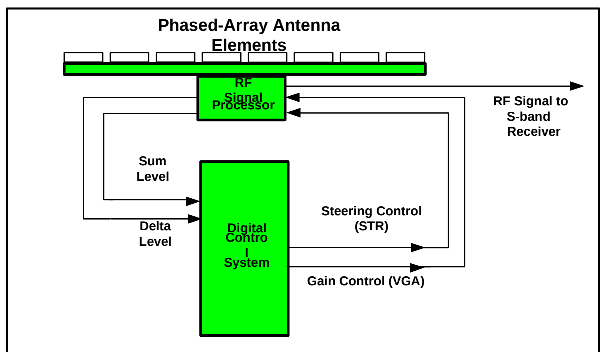
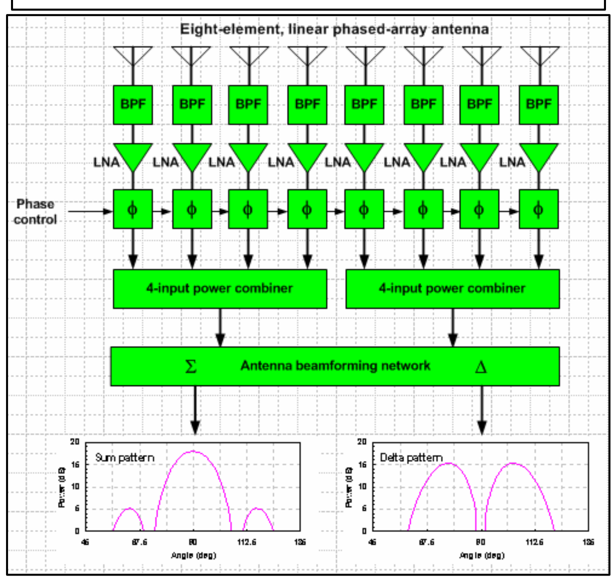


Figure 1
Digital Control System inputs and outputs.



Control System processes Sum and Delta level information and generates a dynamic **Steering Control** signal input for the RF Signal Processor. The **Steering Control** input is a DC voltage level which is used to shift the peak of the antenna's radiation pattern in an optimum direction towards a transmitter. The **Gain Control** (VGA) input signal is a DC level which is used to control the RF signal gain of a pair of variable gain amplifiers within the RF Signal Processor.

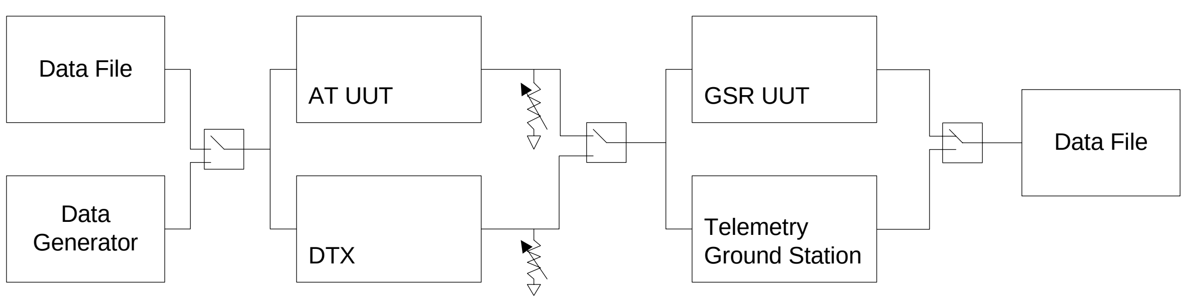
AMS TEST PLAN

The objective of this test plan is to establish functional performance of the AMS and its long range, dynamic tracking wireless communication down link. This will be completed in a series of static ground, and dynamic flight tests. The ground tests provide validation of the AT and GSR elements while the flight demonstration will validate environmental and dynamic flight communication link performance. Flight test resources were provided by NNSA-RSL and the flight tests were conducted at the Nevada Test Site adjacent to Nellis Air Force Base.

Ground Test Plan

The ground test segment will be focused on validation of the transmit and receive elements of the system. A ground test bed is shown in the diagram. The experiments in this phase of the plan are based on known ground station and transmitter assets that produce a known baseline of performance. The AT and GSR functions can be inserted in this testbed and their performance can be benchmarked against the established baseline performance. In this manner both the transmit function and the receive function can be established. In these experiments it is not necessary to have a wireless channel, the testbed can be direct wired. In this demonstration data transfer and voice transfer from the AT to the GSR will completed. Signal characterization will be possible and link quality can be baselined. System elements such as power system, user interface, application and operating system software, baseband data and signal processing, and the wireless interfaces can be characterized.

AMS Static Ground Test Bed

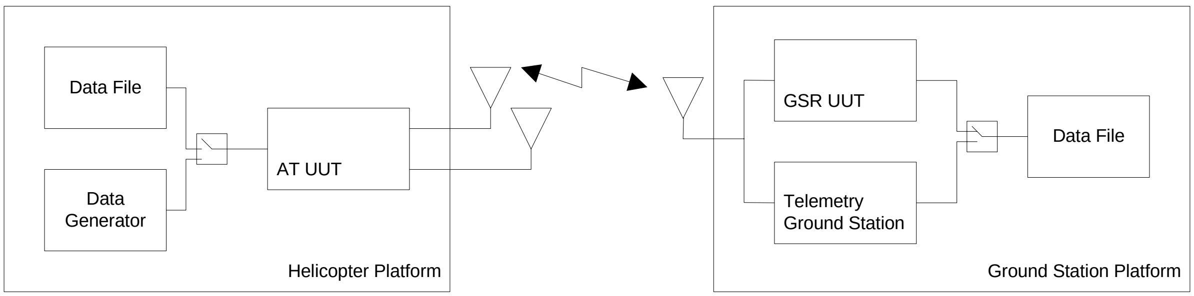


Flight Test Plan

A dynamic flight test segment will be used to demonstrate the environmental and dynamic flight performance of the AT and GSR. The AT will be mounted to an airborne helicopter platform. The GSR will be located within 20 miles line of sight of the AT. The performance of the link will be established over a range of altitude, velocities, and distances. The results from this test bed can be compared to the static ground test bed for benchmarking of performance. The primary difference of this testbed to the static ground testbed is the presence of the dynamic wireless link between the AT and GSR. In this manner effects of Doppler shift, range, multipath, and environmental effects can be studied.

The telemetry ground station will include amplifier, receiver, demodulator, data recording, and storage elements necessary to close the link from the transmitter. In this manner received data can be compared to data transmitted.

AMS Dynamic FlightTest Bed



ANTICIPATED FLIGHT TEST RESULTS

Based on empirical laboratory tests of subsystems, and link analysis, sufficient link margin is anticipated to produce BER of less than 10^{-6}. User interfaces, software, baseband processing elements of the ground testing are expected to progress smoothly. There will be user preferences identified and change requests are anticipated. The dynamic flight tests will reveal actual link margins in the presence of channel noise, multipath fading, Doppler frequency shifts, and shadowing of antennas. These tests will reveal details in terms of spectral distortion, signal strength deterioration, and bit errors leading to degraded link quality.

ACTUAL FLIGHT TEST RESULTS

AMS 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

The 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.

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