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FINAL REPORT

AUTONOMOUS INTEGRATED RECEIVE SYSTEM (AIRS)

REQUIREMENTS DEFINITION

VOLUME I. EXECUTIVE SUMMARY

PREPARED FOR

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1.0 INTRODUCTION

With the advent of today's powerful and inexpensive microprocessors, the concept of distributed processing is proliferating into the design and operation of complex communication and tracking systems. This will be showcased prominantly in the design and operation of the augmented TDRSS and the succeeding TDAS in the 1990's. The Autonomous Integrated Receive System (AIRS) is a first step in this direction in terms of tapping and demonstrating this distributed processing power for the operation of the S-band Single Access (SSA) return link in the White Sands ground terminal.

The purpose of the AIRS study is to develop a receive system capable of (a) autonomous operation and (b) integrated operation. By autonomous operation it is meant here the capability of self configuration, real-time operation, and self diagnostic. Self configuration allows the AIRS to reduce its reliance on a remote executive computer (e.g., the Automated Data Processor Equipment (ADPE) at White Sands). Real-time operation allows the AIRS to react spontaneously to changes in the link conditions, and together with the self configuration capability, to reconfigure itself to react to these changes. Self diagnostic minimizes the possibility of using a malfunctioning AIRS to support a user mission. Of course, self diagnostic also simplifies the maintenance and trouble-shooting procedures. By integrated operation it is meant here that the tasks of Doppler correction, demodulation, detection, and decoding are performed in an integrated manner where useful information are shared and used by ALL portions of AIRS performing these tasks.

This study consists of two phases performed over a period of two years. The first phase of this study was chartered to define the functional requirements of AIRS, to define the testing required to demonstrate its performance, to provide an assessment of the technology and cost involved in such an undertaking, and to prepare a specification based on the above findings. During phase two, a computer simulation model was developed to emulate the AIRS's hardware and software algorithms, and the simulation was used to predict AIRS performance. The emerging TDAS requirements and techniques to enhance the AIRS capabilities were also incorporated into the AIRS baseline during this period.

The results of this study have shown that the AIRS is indeed capable of providing vastly superior performance and operational advantages compared to that of the current equipment. The AIRS can be built with today's technology, with virtually no risk, and at a cost competitive with conventional designs. Moreover, the AIRS is more cost effective over the long run, since the requirements for maintenance and operator attention will be minimized during the operational phase.

2.0 AIRS Operation

The AIRS can be operated either by a remote executive computer or by a local controller. The AIRS also accepts commands from an operator console in both cases. There are three modes of operations: normal mode (NM), flexible data format mode (FDM), and test mode (TM). The AIRS operates autonomously for the first two modes. The test mode operates under operator control.

2.1 Normal Mode

The normal mode will probably be used most frequently. In this mode the AIRS accepts the setup commands from the ADPE defining the user characteristics and the Doppler correction updates to be used during the initial acquisition. The AIRS then takes over. It selects a configuration best suited for the user characteristics and proceeds to acquire the signal. After the signal has been acquired, the AIRS uses the recovered carrier to estimate the incoming signal Doppler. The estimate is then used to update its Doppler corrector to compensate for the signal Doppler. From this point on, the AIRS performs its own Doppler compensation until the mission is over or until the signal is lost and cannot be reacquired without external aids.

Once the signal has been acquired, the AIRS is capable of stand-alone operation without any further intervention from the ADPE. If the signal is lost during this time, the AIRS will try to reacquire the signal. It does so in an intelligent manner by making use of all the information known about the signal right before the signal dropout to reduce the uncertainty region to be searched for reacquisition. This reduces the reacquisition time significantly. If the reacquisition is not successful within a predetermined time interval, the AIRS will notify the ADPE and then wait for a new acquisition command. The time interval is determined by the specified user Doppler characteristics and is equal to the time from signal dropout such that the reacquisition uncertainty range becomes greater than or equal to the initial acquisition range.

The AIRS monitors its operational status continuously and this information is made available to the ADPE. The monitoring data is also made available to a local controller as well as for being displayed on a monitoring console throughout a mission.

The user data characteristics are assumed to be unchanged in the normal mode. The AIRS makes use of this information and configures the carrier recovery and bit synchronizer to attain the best performance achievable. This involves the use of data-aided loop which means that the carrier loop and bit sync must be coupled.

2.2 Flexible Data Format Mode

The flexible data format mode is very similar to the normal mode in terms of its operational procedures. The main difference is in the implementation of the carrier loop and bit sync which are decoupled from each other for the following reason. Some user transmissions consist of signals from different payloads. The data formats and data rates may vary several times during a pass. In the flexible data format mode, the AIRS anticipates these changes and is designed to maintain PN and carrier lock independent of the status of the bit sync and the decoder. This requires the carrier loop and bit sync to be decoupled. The carrier tracking performance is slightly worse than that of the normal mode. In this mode, the AIRS setup commands have to include the anticipated times of data format switching or the ADPE have to inform AIRS about these occurrences through interrupt commands in real-time.

2.3 Test Mode

The AIRS can be configured manually for the purpose of testing or experimentation. Under this mode the AIRS is a general purpose receiver. This mode allows an easy way to try out enhancements and modifications should the need arises. In emergency situations, the test mode can be used to tailor the AIRS configuration to accomodate users experiencing difficulties in conforming to the TDRSS user's constraints.

3.0 SELF DIAGNOSTIC

The AIRS is a digital/software-based receiver. A piece of software is usually trouble free once it has been debugged. The digital hardware employed by the AIRS is highly modular in structure and lends itself to simple testing procedures. A set of built-in tests are included in the software to exercise different portions of the receiver. The receiver electronics can be tested by injecting a test signal into the AIRS input and monitoring the signal quality at various intermediate points. The particular test where a failure occurs can be used to locate the problem for fault isolation.

The self-test is a standard power-up procedure. Upon a system anamoly during operation, the AIRS will aso perform a self-test to verify that the anamoly is not caused by its own failure.

4.0 MAINTENANCE

The hardware/software-based implementation also requires low maintenance. Software is virtually maintenance free. The use of digital hardware minimizes the need for periodic calibrations. In addition the cost of duplicating digital hardware is very little and the cost of duplicating software is almost nonexistent. Therefore, enough redundancy can be built into the AIRS so that the MTBF can be made very long and the need for maintenance can be virtually eliminated.

From time to time new requirements will arise that warrant changes in operation procedures and the receiver characteristics. These modifications can be accomodated by merely changing the AIRS software. This is much less expensive than modifying a conventional receive system.

5.0 AIRS SYSTEM ARCHITECTURE

The AIRS can be divided into three distinct subsystems: (a) PN subsystem, (b) demodulator subsystem and (c) software control subsystem. The PN subsystem uses charge-coupled device (CCD) PN matched filters to improve acquisition at low data rates. It uses a four channel sequential search to acquire at higher data rates. And it uses a double tau-dithered loop for tracking. The CCD implementation is inherently digital in nature. The signal is sampled at the envelope detector output for sequential acquisition and tracking processing. From that point on, the PN subsystem is implemented in software.

The demodulator is highly modular. Two identical channels are used and each consists of an analog-to-digial (A/D) conversion subsystem and a digital signal processing (DSP) subsystem. The purpose of the DSP subsystem is to perform high speed digital processing on the A/D samples so that the resultant output samples are output at a rate compatible with the slower processing speed of the software. The software completes the various tracking loops for demodulation purposes.

The software resides in the AIRS processor and controls the various functions such as sequencing of acquisition, reacquisition, receiver configuration, parameter selection, and interfacing with the external world.

6.0 PERFORMANCE

The key performance characteristics of the AIRS based on the AIRS simulation are summarized in Table I. The performance requirements are given for the worst case signal-to-noise ratios, user dynamics, and data characteristics combinations. The performance will be improved for all other combinations. The most striking area of performance improvement over the current TDRSS equipment is a twenty-fold decrease of acquisition time. The AIRS also provides (a) reliefs from current TDRSS system waivers on I:Q power ratios and data modulation formats, (b)

Table I. AIRS Key Performance Characteristics.

PARAMETER	PERFORMANCE REQUIREMENT
ACQUISITION PROBABILITY	> 90%
ACQUISITION TIME (TOTAL)	< 3 sec
• PN	< 2 sec
• CARRIER FREQUENCY (FLL)	< 0.8 sec
• CARRIER PHASE (PLL)	< 0.2 SEC
REACQUISITION TIME (TOTAL)	< 2 sec
• PN	< 1 sec
• CARRIER FREQUENCY (FLL)	< 0.8 sec
• CARRIER PHASE (PLL)	< 0.2 sec
PHASE JITTER	
• C/N_0 > 28 dB-Hz	< 17.3°
CYCLE SLIP	
• C/N_0 > 33 dB-Hz	> 90 min
• C/N_0 > 28 dB-Hz	> 1 min
BIT ERROR RATE	2.5 dB from theory
PN CODE TRACKING	
• CODE JITTER	< 2 %

relaxation of some S-805 constraints, (c) additional capability for I-Q channel ambiguity resolution, and (d) accomodation for implementing RFI mitigation schemes. Detailed discussions on these capabilities can be found in Vol. II of the Final Report.

7.0 RECOMMENDED FUTURE WORK AREAS

Aside from the prototype activity, there are two areas that warrant future efforts. The first area is related to the simulation software. Since the AIRS concept and architecture can be applied equally well to other NASA receiver developments, it is worthwhile to expand the capability of the software and make it more accessible to other users. In order to accomplish this, the simulation packages will require better documentation and perhaps a tutorial. In addition, it will need a more sophisticated user interface so that it can be used by less experienced personnel. Naturally, the software must be updated from time to time to incorporate improvements as well as to handle other modulation schemes.

LinCom can also provide system engineering support during the prototype development. This support would include review and evaluation of the vendor's design and progress. The simulation tool will be used to track the vendor's design and analysis will be provided as needed.

8.0 ORGANIZATION OF THE REPORT

Aside from this executive summary, the final report for AIRS consists of three more volumes. Volume 2 documents the work performed during the phase 1 study. The phase 2 simulation work is documented in Volume 3. Volume 4 is the functional specification for AIRS. In addition, a simulation software package has been installed in the Goddard CLASS computer.