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**ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)**

**PHASE I: INDUSTRIAL/ACADEMIC EXPERIMENTERS**

**FINAL TECHNICAL REPORT**

**NASA GRANT NO. NAGW - 2389**

**PROJECT DIRECTOR: JAMES E. MAISEL**

**CO - DIRECTOR: ROBERT W. NOWLIN**

**PERIOD COVERED: 4-1-91 TO 12-31-92**

**DEPARTMENT OF ELECTRONICS AND COMPUTER TECHNOLOGY**

**ARIZONA STATE UNIVERSITY**

**TEMPE, ARIZONA 85287-6606**

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## TABLE OF CONTENTS

|      |                             |   |
|------|-----------------------------|---|
| I.   | ABSTRACT .....              | 1 |
| II.  | HISTORICAL BACKGROUND ..... | 2 |
| III. | GRANTEE'S ACTIVITIES .....  | 3 |
|      | APPENDIX A .....            | 6 |
|      | APPENDIX B .....            | 7 |

**ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE (ACTS)**

**PHASE I: INDUSTRIAL/ACADEMIC EXPERIMENTERS**

**FINAL TECHNICAL REPORT**

**I. ABSTRACT**

This report presents the work done at Arizona State University under the ACTS Experimenters Program. The main thrust of the Program was to develop experiments to test, evaluate, and prove the commercial worthiness of the ACTS satellite which is scheduled for launch in 1993. To accomplish this goal, meetings were held with various governmental, industrial, and academic units to discuss the ACTS satellite and its technology and possible experiments that would generate industrial interest and support for ASU's efforts. Several local industries generated several experiments of their own. The investigators submitted several experiments of educational, medical, commercial, and technical value and interest. The disposition of these experimental proposals is discussed in this report.

## II. HISTORICAL BACKGROUND

Since one of the main thrusts of the research project is to develop a set of interdisciplinary industrial/academic experiments for the ACTS Program, the Department of Electronics and Computer Technology at Arizona State University (ASU) sponsored an ACTS Symposium in the Spring of 1990. The purpose of this meeting was to invite technical personnel from metropolitan Phoenix and Ogden, Utah.

A high percentage of the attendees were persons that held a position on the industrial advisory board for the Department of Electrical Engineering and the Department of Electronics and Computer Technology at ASU. The group heard presentations about the ACTS Experimenters Program from personnel from NASA Headquarters, NASA Lewis Research Center, Motorola Strategic Electronics Division (SED) and the College of Engineering and Applied Sciences at ASU. Both technical and administrative details were explained about the ACTS satellite and the ACTS Experimenters Program and its impact on future satellite communications systems for the rest of the century and beyond.

A questionnaire was sent to each industrial participant asking them to indicate their interest and the type of experiment they envisioned that could be performed using the ACTS satellite. There were only three positive responses from the original group of attendees. They were American Express Worldwide Telecommunications, Motorola SED, and Weber State College (Ogden, UT). Because of other research commitments, Weber State College withdrew from the ACTS Experimenters Program.

American Express Worldwide Telecommunications submitted an experiment that links the ACTS system between Phoenix, Az. and Mexico City, Mexico to transfer credit card data between these two cities. They presently have such a satellite link. A performance comparison between the ACTS link and the present link would be very beneficial to American Express as well as the satellite community in general. One feature that American Express wants to test is the dynamic rain fade compensation system built into the ACTS satellite. During certain seasonal periods, both Mexico City and Phoenix experience substantial rainfall over relatively short time periods. By comparing the bit-error-rate (BER) of both links during a rain fade period, it can be determined how well the rain fade compensation system enhances the ACTS satellite performance. The effect of rain fade becomes one of the dominant problems at 20/30 Ghz, the frequency used by ACTS.

Motorola SED submitted four experimental concepts. They are: Characterization of Transmit Window, Coding Gain Evaluation, Development of a High Bit Rate Ground Terminal, and the Performance and Characterization of

the ACTS satellite's Motorola-built Baseband Processor.

Faculty members from the Department of Computer and Electronics Technology at ASU generated ACTS experiments that would evaluate the frequency division multiple access (FDMA) performance including intermediate frequency matrix switching in a high bit rate mode. Those tests would evaluate BER performance in the presence of various expected and unexpected link and internal system impairments such as intermodulation distortion due to multiple carriers. Time division multiple access testing would be conducted to measure performance advantages and disadvantages relative to communications in an FDMA environment.

Both Professors Maisel and Nowlin attended the ACTS Conference '90 in Las Vegas, Nevada on October 17-18, 1990. They were briefed by representatives from organizations involved with the ACTS Experimenters Programs about their individual experimental concepts. Presentations were given by ACTS program staff members who described the present status of the program, specifically ACTS Satellite Program Overview, Experimenters Program Overview, and Ground Terminals.

The second day dealt with more details from over ten experimenters. The experiments ranged from defense applications to super computer applications.

### **III. GRANTEE'S ACTIVITIES**

#### **A. Meetings**

On July 15, 1991 a meeting was held at NASA Lewis Research Center (Cleveland, Ohio) between Barry Fairbanks, ACTS Application Engineer, and Professor James E. Maisel. Topics to be addressed at the July 30th meetings at ASU were discussed. One of the main topics dealt with the implementation of the proposed American Express Experiment. This experiment involved the establishment of a temporary communications link between Mexico City, Mexico and Phoenix, Az. Since it effectively involves two federal governments, the logistics can become somewhat complex so our intent was to investigate various possible scenarios. Mr. Gregorio Vasquez was introduced at the meeting as the person responsible to look at establishing the ground terminal in Mexico City.

At the close of the meeting Professor Maisel toured the ACTS ground terminal at Lewis Research Center with Barry Fairbanks. Some of the testing facilities as well as where the final control room would be located were shown during the tour.

A meeting was called on July 30, 1991 at ASU. Representatives from American Express, Motorola SED, NASA Lewis Research Center, and ASU were present. This was the first opportunity for all ACTS experimenters in the metropolitan Phoenix area to meet and discuss their interest in the ACTS Experimenters Program.

The American Express representative (Allen Neely) had a lengthy dialogue with the Motorola SED representative (Roger Thomas) in regard to the time schedule for the American Express Experiment. Mr. Neely indicated that the rainy periods at Mexico City and Phoenix would entail heavy use of the ACTS system by American Express. Other experiments would have to be scheduled around American Express experimental activities. The other representatives attending the meeting felt that this request was acceptable providing that the experimental schedule by American Express is well defined in start-up and shut-down.

Motorola SED (Roger Thomas) is planning to purchase a low-bit-rate earth station that will be modified to meet the experimental objectives of Motorola SED. The actual purchase date and the detailed station modifications could not be addressed at this meeting because of the long lead time prior to launch (Spring 1993).

Dr. Robert Nowlin (co-investigator) attended the ACTS Conference '91 on August 29 - 30, 1991 in San Jose, California. On the first day, the conference addressed the following topics: ACTS Program Overview, Communications System Description, Flight System Development Status, and Experiment Program Status. On the second day, application and hardware development were addressed for the VSAT, single-hop VSAT, Ka-band mobile, and super computer network terminals.

In order to increase the awareness and the potential of the ACTS experimenters Program, a meeting was called on September 13, 1991 at ASU. Representatives from Arizona Public Service (APS), a local electrical power company, and ASU attended. The focal point of the meeting was to discuss cooperation between APS and ASU in cooperative ACTS experiments and the extent of support APS would contribute to this effort. APS indicated several different types of experiments. They are: telemetering information from their outlying areas in Northern Arizona, transfer of billing information between various APS offices, and sending system drawings to various locations in Arizona.

## **B. Development of ACTS Experiments**

A set of experiments for the ACTS system were developed by Professors Maisel and Nowlin and submitted to the Office of Commercial Programs, NASA

Headquarters, Washington, DC in response to NASA Experiment Opportunity Announcement (EOA) for ACTS. (Experiments developed by American Express and Motorola SED were sent directly to NASA Lewis Center.) The experiment set that was developed by Professors Maisel and Nowlin are listed in Appendix A. The titles of the experiments are: (1) Effect of Rainfall on Bit Error Rate of the ACTS System, (2) Evaluation of the ACTS System for Educational TV, (3) Evaluation of ACTS for Medical Diagnosis, (4) Evaluation of ACTS for Customer Service Information Transmittal, and (5) Evaluation of ACTS for Engineering Drawing Transmittal. Experiments two through four were placed in Category III. For proposals in Category III, NASA will work with the proposers to develop other investigation scenarios to meet the proposal requirements. We have not had a response from NASA at the time of writing this report.

The experiment proposal, "Effect of Rainfall Rate on the Bit Error Rate of the ACTS System" did not receive funding because the Experiment Opportunity Announcement (EOA) for ACTS had to be funded by the experimenter's own source of funds. However, it was suggested that NASA Research Announcement (NRA) entitled "Advanced Communications Technology Satellite: Propagation Experiments Implementation Program" NRA-92-LERC-1 was designed to emphasize participation by academic institutions.

A proposal, "The Effect of Weather Conditions, Channel Equalization, and Echo Cancellation on ACTS System" was submitted to NASA Lewis Research Center. See Appendix B. The status of this proposal is pending at this time.

## APPENDIX A



September 10, 1991

Mr. Clarence Pittman  
Office of Commercial Programs  
NASA Headquarters  
Code C  
Washington, DC 20546

Dear Mr. Pittman:

This letter states that Professors James E. Maisel and Dr. Robert W. Nowlin in the Department of Electronics and Computer Technology at Arizona State University (Tempe, AZ) intend to participate in the NASA ACTS Experiments Program. The objective of this experiment to be conducted is to study bit-error-rate (BER) under various weather conditions.

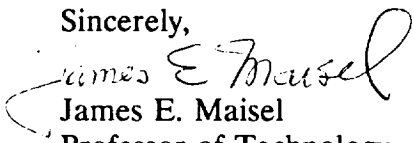
The plan is to use the ACTS ground station facilities at Motorola SED that is located in Chandler, Az. A known set of binary bits will be sent to the ACTS satellite and returned to the ground station at Motorola. Assuming that all electronic systems are functioning properly, there should be a strong correlation between BER and weather conditions. Since the yearly rainfall in the Phoenix area is approximately 7 inches, a good data base can be established. However, there are periods when the precipitation is heavy over a short time interval. By periodically sending the same set of bits, say every 15 minutes, to the base-band processor and having the bits returned, the effect of rain on BER could be studied. If the experiment is successful, other ACTS ground stations could conduct the same experiment to determine the impact that rain has on the BER at their ground station location.

It appears that the following items will be required to perform the experiment:

- \* Financial support for a faculty's release time.
- \* Financial support for a graduate student.
- \* Appropriate BER counter.
- \* Rain gage at Motorola SED.
- \* Financial support for miscellaneous items.

If you have questions, please contact Dr. Robert W. Nowlin, (602) 965-2673. or myself (602) 965-3976.

Sincerely,

  
James E. Maisel  
Professor of Technology

JEM:cco \acts-ber.jem

cc: Barry Fairbanks  
Robert W. Nowlin

# Arizona State University

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College of Engineering and Applied Sciences  
Department of Electronics & Computer Technology  
Tempe, Arizona 85287-6606  
602/965-3137

September 25, 1991

Mr. Clarence Pittman  
Office of Commercial Programs  
NASA Headquarters  
Code C  
Washington, DC 20546

Dear Mr. Pittman:

This letter states that Professors James E. Maisel and Dr. Robert W. Nowlin in the Department of Electronics and Computer Technology at Arizona State University (Tempe, Arizona) intend to participate in the NASA ACTS Experiments Program. The objective of this experiment is to compare the quality of video/audio over the National Technological University (NTU) System and the ACTS System.

In the Spring of 1992, ASU will be broadcasting television courses over the NTU System. This system will use a digital, rather than an analog, format and a frequency compression algorithm to conserve the bandwidth. The NTU will use the KU band with a rate of approximately 3 Mbps per television channel. Courses will be broadcast to other universities in the United States. Our interest is to establish an ACTS link between the ground station facilities at Motorola SED (Chandler, Arizona) and the University of Arizona (Tucson, Arizona). This link can be used to compare the NTU and ACTS systems.

Since the ACTS ground station is located several miles from ASU, the current TV microwave terrestrial link (which supports a television analog signal) between ASU and Motorola SED will be needed in this experiment. At Motorola, the TV analog signal must be converted to a digital format before it is transmitted to the ACTS satellite.

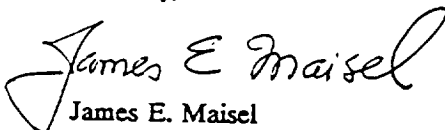
Because it is an experiment, the participants (Maisel and Nowlin) believe that the initial phase be conducted during off-program-hours so that the disruption is minimal. If successful, a scheduled course could be offered over both systems for comparison purposes.

It appears that the following items will be required to perform the experiment:

- Financial support for faculty release time;
- Financial support for a graduate student;
- Analog-to-digital interface;
- Financial support for miscellaneous items.

If you have questions, please contact Dr. Robert W. Nowlin (602) 965-2673 or myself (602) 965-3976.

Sincerely,



James E. Maisel  
Professor of Technology

JEM:cco \acts-x.ltr

cc: Barry Fairbanks  
Robert W. Nowlin  
Albert L. McHenry

# Arizona State University

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College of Engineering and Applied Sciences  
Department of Electronics & Computer Technology  
Tempe, Arizona 85287-6606  
602/965-3137

September 18, 1991

Mr. Clarence Pittman  
Office of Commercial Programs  
NASA Headquarters  
Code C  
Washington, D.C. 20546

Dear Mr. Pittman:

This letter states that Professors James E. Maisel and Dr. Robert W. Nowlin in the Department of Electronics and Computer Technology at Arizona State University (Tempe, AZ) intend to participate in the NASA ACTS Experiments Program. The objective of this experiment is to study the feasibility and viability of using television pictures sent via satellite for medical diagnosis purposes. There is a shortage of many qualified medical specialists especially in rural areas of the country. Many of the specialists like pathologists must commute from site to site to perform their duties. Specialists practicing in a rural setting may have occasion to seek consulting opinions from regional centers or may need to refer patients for further management at urban centers. Presently, these may only be handled by shipping specimens to a second site for consulting opinions. Medical technologists examining fluids and specimens at a remote site may also have to ship slides to a distant site where a pathologist is located for his review and interpretation.

If each of these facilities (rural hospitals, laboratories, and urban medical centers) had ground terminals, television images of the tissues, slides, samples, etc. could be transmitted from one site to the other for consulting and diagnostic opinions. This would greatly save on travel time of the specialists and greatly benefit patients by providing a more rapid and timely interpretation of test results and potentially provide for more efficient definitive diagnosis and treatment with the attendant potential cost savings.

The plan will be to use the ACTS ground station facilities at Motorola SED located in Chandler, Arizona. A television image of a tissue or cytology or hematology slide to be studied would be sent to the ACTS satellite and returned to the ground station at Motorola where they would be viewed on a monitor and the quality and resolution of the images evaluated by a pathologist to determine adequacy of the image quality for accurate diagnosis. Ideally, audio links as well as video links would be necessary so that the viewing

Mr. Clarence Pittman  
September 18, 1991  
Page two

recipient of the images might remotely direct viewing field changes at the sending site. If normal TV images should prove to be inadequate for diagnostic purposes, then slow scan and HDTV images could be broadcast and received for comparisons. If the experiment is successful, histology, hematology and cytology consultations might be centralized. This would then result in more efficient utilization of a service in short supply and potentially result in significant cost savings.

It appears the following items will be required to perform the experiment:

- \* Financial support for a faculty's release time;
- \* Financial support for a graduate student;
- \* T1 or T3 interface to the ground station;
- \* TV - Microscope interface for scanning the specimen;
- \* Financial support for miscellaneous items.

If you have questions, please contact Professor James Maisel, (602) 965-3976, or myself (602) 965-2673.

Sincerely,



Robert W. Nowlin, Ph.D.

RWN:cco \bob.rwn

cc: Barry Fairbanks  
James E. Maisel  
Albert L. McHenry

# Arizona State University

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College of Engineering and Applied Sciences  
Department of Electronics & Computer Technology  
Tempe, Arizona 85287-6606  
602/965-3137

September 18, 1991

Mr. Clarence Pittman  
Office of Commercial Programs  
NASA Headquarters  
Code C  
Washington, DC 20546

Dear Mr. Pittman:

This letter states that Professors James E. Maisel and Dr. Robert W. Nowlin in the Department of Electronics and Computer Technology at Arizona State University (Tempe, Az.) intend to participate in the NASA ACTS Experiments Program. The objective of this experiment is to study the feasibility and reliability of transmitting electric utility customer service information from the main office out to the division offices. In this experiment, continuous operation and reliability are of critical importance.

The plan is to use the ACTS ground station facilities at Motorola SED that is located in Chandler, AZ. Customer service from the utility's central office would be transmitted by normal means to the Motorola facility, then to the ACTS satellite by the Motorola ground station, and finally to the division office via the ACTS steerable antenna. Since continuous operation and reliability in various kinds of weather are critical, it is anticipated that this experiment might run for eight (8) hours per day over several months so that various kinds of weather could be experienced.

It appears that the following items will be required to perform the experiment:

- \* Financial support for a faculty's release time;
- \* Financial support for a graduate student;
- \* T1 interface to the ground station;
- \* Financial support for miscellaneous items.

If you have questions, please contact Professor James Maisel, (602) 965-3976, or myself (602) 965-2673.

Sincerely,



Robert W. Nowlin, Ph.D.

RWN:cco \aps1.rwn

cc: Barry Fairbanks  
James E. Maisel  
Albert L. McHenry

# Arizona State University

---

College of Engineering and Applied Sciences  
Department of Electronics & Computer Technology  
Tempe, Arizona 85287-6606  
602/965-3137

September 18, 1991

Mr. Clarence Pittman  
Office of Commercial Programs  
NASA Headquarters  
Code C  
Washington, DC 20546

Dear Mr. Pittman:

This letter states that Professors James E. Maisel and Dr. Robert W. Nowlin in the Department of Electronics and Computer Technology at Arizona State University (Tempe, Az.) intend to participate in the NASA ACTS Experiments Program. The objective of this experiment is to study the viability of transmitting electric utility design drawings from the engineering center to the generating stations.

The plan is to use the ACTS ground station facilities at Motorola SED that is located in Chandler, AZ. Digitized engineering drawings would be transmitted from the Motorola site to the ACTS satellite for retransmission to the generating stations via the steerable antenna. This experiment requires sending a large volume of data for a short period of time. This experiment would also test the feasibility of transmitting CAD drawings using virtually the same techniques. If successful, the experiment could establish a commercial alternative to fiber optics or high speed ground microwave links.

It appears that the following items will be required to perform the experiment:

- \* Financial support for a faculty's release time;
- \* Financial support for a graduate student;
- \* T1 interface to the ground station;
- \* Financial support for miscellaneous items.

If you have questions, please contact Professor James Maisel, (602) 965-3976, or myself (602) 965-2673.

Sincerely,



Robert W. Nowlin, Ph.D.

RWN:cco \aps2.rwn

cc: Barry Fairbanks  
James E. Maisel  
Albert L. McHenry

## APPENDIX B

# Arizona State University

---

College of Engineering and Applied Sciences  
Department of Electronics & Computer Technology  
Tempe, Arizona 85287-6606  
602/965-3137

December 30, 1991

NASA Lewis Research Center  
Attn.: Leonard Rizzolla  
21000 Brookpark Road, MS 54-6  
Cleveland, Ohio 44135-3191

Dear Leonard Rizzolla:

This letter states that Professors James E. Maisel and Dr. Guoliang Zeng in the Department of Electronics and Computer Technology at Arizona State University (ASU, Tempe, AZ) intend to participate in the ACTS Propagation Experiments Implementation Program (NRA-92-LERC-1). The objective of this experiment is to study bit-error-rate (BER) under various weather conditions.

The plan is to use the ACT earth station at Motorola SED and a propagation terminal located at ASU. A predetermined set of binary bits will be sent periodically to the ACTS satellite and returned to the earth station at Motorola SED. Assuming that all electronic systems are functioning properly, there should be a strong correlation between BER and weather conditions. The beacon power level will be monitored by a propagation terminal (located at ASU) so that fades due to weather conditions can be tracked. Since the yearly rainfall in the Phoenix area is approximately 7 inches, a good data base can be established. However, there are periods when the precipitation is heavy over a short time interval. By periodically sending the same set of bits to the ACT's base-band processor and having the bits returned, the effect of weather conditions on BER can be studied.

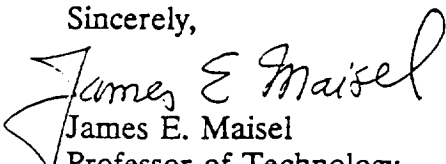
Also, as part of this study, we want to investigate the possibility of using infinite impulse response equalization and echo cancellation techniques to reduce the intersymbol interference. Intersymbol interference has a strong impact on the value of the BER.

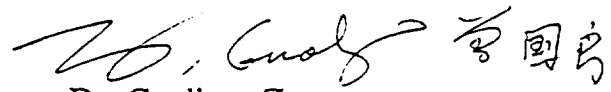
It appears that the following items will be required to perform the experiment:

- \* Propagation earth terminal and related equipment.
- \* Appropriate BER counter.
- \* Rainfall and temperature measuring devices at Motorola SED.

If you have questions, please contact me at (602) 965-3976.

Sincerely,

  
James E. Maisel  
Professor of Technology  
JEM:cco

  
Dr. Guoliang Zeng  
Assistant Professor of Technology





***THE EFFECT OF WEATHER  
CONDITIONS, CHANNEL  
EQUALIZATION, AND ECHO  
CANCELLATION ON THE ACTS  
SYSTEM***

Proposed to the National Aeronautics and Space Administration,  
Lewis Research Center

Submitted February, 1992

Submitted through the Telecommunications Research Center  
by James E. Maisel and Guoliang Zeng  
Department of Electronics & Computer Technology  
College of Engineering & Applied Sciences  
Arizona State University  
Tempe, Arizona 85287-6606

## TABLE OF CONTENTS

|      |                                |       |
|------|--------------------------------|-------|
| I.   | ABSTRACT .....                 | 2 - 3 |
| II.  | PROJECT DESCRIPTION .....      | 4 - 8 |
|      | A. OBJECTIVES                  |       |
|      | B. HISTORICAL BACKGROUND       |       |
|      | C. EXPERIMENT DESCRIPTION      |       |
|      | EXPERIMENT A                   |       |
|      | EXPERIMENT B                   |       |
|      | EXPERIMENT C                   |       |
| III. | VITAE .....                    | 9-11  |
|      | A. JAMES E. MAISEL             |       |
|      | B. GUOLIANG ZENG               |       |
| IV.  | FACILITIES AND EQUIPMENT ..... | 12-13 |
| V.   | PROJECT BUDGET .....           | 14-15 |

## **I. ABSTRACT**

## The Effect of Weather Conditions, Channel Equalization, and Echo Cancellation on the ACTS System

### I. ABSTRACT

The objective of this proposal is to (1) process data from the ACTS propagation terminal located on the campus of Arizona State University, (2) investigate the use of a fast and robust IIR adaptive algorithm for improvement of channel equalization and echo cancellation, (3) test the results of the IIR adaptive algorithm using a modified low-bit-rate (LBR) earth station located at Motorola SED (Chandler, AZ). Presentation of each phase is listed under "Project Description."

Using an ACTS propagation terminal and an LBR earth station, we propose to use bit-rate-error (BER) instruments to measure any improvement in the channel equalization and echo cancellation using an IIR adaptive system. By monitoring the signals from the propagation and LBR terminal, correlation between BER and dynamic weather conditions should be high. Because weather dynamics is time-varying and random, the channel equalization and echo cancellation should be adaptive. Ideally, we want to use ACTS system periodically for relatively short periods of time, but would be flexible to accommodate other experimental users.

At this time, we assume that the modified LBR will be capable of handling T3. Motorola SED is scheduling time for the two external experimenters (ASU and American Express.) Details of experimental time scheduling still must be addressed.

As part of this proposal, we are allocating \$10,000 in our budget for BER instruments. The determinative decision on the BER equipment will depend on final modified design of the LBR so it would not be prudent at this time to specify BER manufactures and models. If NASA has the appropriate BER instruments, this certainly would be acceptable.

Presently, we anticipate using just ACTS baseband processor for BER measurements since the antenna beam hopping rapidity is sufficient to handle the variation that might occur in weather dynamics. However, if time permits, we could perform our testing using the ACTS microwave switch matrix mode.

## **II. PROJECT DESCRIPTION**

## II. PROJECT DESCRIPTION

### A. Objectives

The objectives of this proposal for first class experiments are:

- To perform radio wave propagation measurements of attenuation due to rain fade, rain fade rate, and rain fade duration with an ACTS propagation terminal located on the campus of Arizona State University (ASU).
- To investigate the use of a fast and robust algorithm using adaptive infinite impulse response (IIR) for improvement of channel equalization and echo cancellation.
- To determine the impact that weather conditions have on bit-error-rate (BER) associated with the ACTS system by correlating the beacon signal level from the ACTS propagation terminal at ASU with the BER measured at a modified low-bit-rate earth station (LBR) located at Motorola SED (Chandler, AZ).

### B. Historical Background

Because the K-a band (20/30 GHz) is at a higher frequency than K-u, it has advantages such as smaller antennas for a given antenna gain. However, on the downside, the K-a band presents a considerable challenge because of severe rain fade degradation.

Arizona State University (ASU) offers an excellent environment for propagation studies because it is located in the metropolitan Phoenix area where the annual rainfall is approximately 7 inches. The weather pattern in the Phoenix area is somewhat unique in that there are dry periods followed by heavy rain over relatively short periods, especially during the summer monsoons. This type of rain pattern does offer an excellent data base for propagation studies.

The College of Engineering and Applied Sciences (CEAS) at ASU is completing a new research facility that will house the Center for Telecommunications Research (TRC). Cable raceways exists between the roof and the TRC for a propagation terminal.

The Department of Electronics and Computer Technology, which is in CEAS, has been very active in the ACTS Program. The principal investigator was awarded a grant for the proposal entitled "Advanced Communications Technology Satellite (ACTS) Phase I: Industrial/Academic Experimenters." Through a series of meetings with Motorola SED and American Express, a set of four industrial experiments were proposed. Three experiments (Motorola SED) will focus on the ACTS system, while the other experiment

(American Express) will establish a transmission link between its headquarters (Phoenix, AZ) and an earth station located in Mexico City, Mexico for a comparison study between the ACTS system and its present satellite link. The ACT's steerable antenna will be required. As part of its experiment, American Express will require rain fade information both in Phoenix and Mexico City.

ASU submitted five experiments as part of Phase I to NASA Headquarters in Washington, D.C. Also, ASU has been informed that the Motorola SED and American Express have submitted their experiments.

Motorola SED is in the process of purchasing an LBR-2 earth station that will be upgraded to a T3 capacity. Two ACTS earth stations in the same general locale (8 mile separation), one located at Motorola SED (Chandler, AZ) and the other at ASU (Tempe, AZ), should be valuable for propagation and rain fade experiments.

The above activities with Motorola, American Express, and Phase I of the ACTS program illustrates the commitment that ASU has toward development of telecommunications. Prior to Phase I, the Department of Electronics and Computer Technology sponsored an ACTS symposium in 1990. Industrial, governmental, and academic personnel attended the meeting that described the ACTS Program.

### C. Experiment Description

The propagation measurement of an attenuation experiment (Experiment A) is a stand-alone-experiment that can meet the proposal's first objective. A simulation of a fast and robust algorithm using adaptive IIR (Experiment B) for channel equalization and echo cancellation can be treated as a stand-alone experiment. However, the details on measuring the BER during fade conditions cannot be completely proposed at this time, because the earth station has not been purchased and modification details have not been developed. Based on the purchased and modification of the LBR earth terminal by Motorola SED, our third objective will be Experiment C.

#### Experiment A

Because ASU is located in a region where the weather pattern is arid with dispersions of summer monsoons, it is an excellent location for performing radio wave propagation measurements of attenuation due to rain and particulate scintillation. These large variations in weather conditions at one locale offer an excellent annual attenuation data base.

Over the 24 month experimental period, we should be able to generate enough rain rate statistics using the propagation terminal to aid in the understanding of the meteorological processes that cause the attenuation of the radio waves. Because the earth propagation terminal is passive, the fade characterization can only be described at

one frequency (20 GHz). However, if the terminal is capable of receiving vertical polarization (20.185 GHz) and horizontal polarization (20.195 GHz) more information can be gained about radio wave propagation fades. If a feed cross-polarizer and a switchable mixer oscillator can be used, the effects of polarization on rain fade can be investigated.

Raw and preprocessed data will be transferred monthly to the control facility and an exchange of information among the various propagation terminals will be conducted via the control facility. Because the impact of weather conditions is so important at high frequencies (20/30 GHz), we plan to participate in the periodic NASA Propagation Experimenters meetings and ACTS Propagation Studies Workshops to present our results.

### **Experiment B**

Besides the adverse fade characteristic at 20/30 GHz, another problem associated with satellite communications is channel equalization. When a radio wave propagates through a medium such as clouds, rain, etc., the signal tends to be dispersed or spread-out in time. It can cause a partial energy shift from one binary slot or bin to an adjacent slot causing the BER to increase. This is referred to as intersymbol interference (ISI). This is a very important topic in high speed digital communications. It can be expected that availability of higher modulation format due to better equalization will have a large impact on communications.

In order to reduce the intersymbol interference due to dispersion, a form of adaptive processing is required because weather is time varying. The finite impulse response (FIR) adaptive processing technique has been used in satellite communication systems for channel equalization for many years because it is inherently stable. However, one major disadvantage of the adaptive FIR processor is that it requires a high order processing system, hence a large amount of computations.

The infinite impulse response (IIR) adaptive processor offers significant reduction in computation time because of the inherent feedback. It is our opinion that the adaptive IIR processor will be a very active area in telecommunications research. The disadvantage of the adaptive IIR processor is the possibility of instability if not properly designed. Unlike most output-error type algorithms for adaptive IIR systems, the hyperstable adaptive recursive filter (HARF) algorithm [1] is globally convergent, but the requirement for a strictly positive and real (SPR) transfer function is impractical [2]. Therefore, the investigation of practical and globally convergent algorithms is of paramount concern, especially in satellite telecommunications.

We propose that a stepsize-varying algorithm for adaptive recursive filters (SVARF) [3] be investigated for use in the ACTS system. From theoretical analysis and computer simulations, the SVARF algorithm is much more robust and faster in convergence than the HARF algorithm and the computational load of the SVARF



algorithm is a fraction of the HARF's algorithm. The SPR requirement is completely removed in the SVARF algorithm. The SVARF can also be used for echo cancellation on the ACTS system.

### Experiment C

Predicated on Motorola SED purchasing and modifying an LBR earth terminal and successful results from Experiment B, we propose to implement the SVARF algorithm, using the ACTS system to determine the BER improvement using the SVARF processor. During the adaptive or learning period, a known bit pattern will be sent and returned to the earth terminal at Motorola SED. The coefficients of the SVARF processor will be adjusted according to the SVARF algorithm to minimize the BER. The SVARF processor will take into account any dynamic weather conditions.

### References

- [1] C. R. Johnson, Jr. "A convergence proof for a hyperstable adaptive recursive filter," *IEEE Trans. on Info. Thy.*, Vol. IT-25, pp 745-749, Nov., 1979.
- [2] Guoliang Zeng, "Adaptive Digital Filtering," PhD Dissertation, Department of EE, ASU, Tempe, AZ 85287, 1990.
- [3] Guoliang Zeng, "A Fast & Robust Algorithm for IIR Filter," 2nd International Conference on Industrial & Applied Math. July, 1991.

### III. VITAE

JAMES E. MAISEL

Professor of Technology  
Electronics and Computer Technology

Degrees: Post Graduate Studies:

|                |  |
|----------------|--|
|                | Electrical Engineering, Worcester Polytechnic Institute, 1970-72 |
|                | Electrical Engineering Arizona State University, 1979-80         |
| MSEE           | Ohio State University, 1957                                      |
| BSEE           | Cleveland State University, 1955                                 |
| BSES (Physics) | Cleveland State University, 1955                                 |

Academic Experience:

1985- Arizona State University, Professor of Technology  
1976-85 Cleveland State University, Member of the Graduate College Faculty  
1958-85 Cleveland State University, Instructor, Assistant Professor, Associate Professor, and Professor of Electrical Engineering  
1955-58 Ohio State University, Instructor, Department of Electrical Engineering

Industrial Experience (Summers)

1981,82 NASA Lewis Research Center, Space Communications Division, Cleveland, OH, Communications Engineer  
1980 Goodyear Aerospace Corporation, Litchfield Park, Arizona, Consulting Engineer  
1972-77 NASA Lewis Research Center, Basic Materials Laboratory, Cleveland, Ohio  
1961,62,65 Ohio Bell Telephone Company, Cleveland, Ohio, Microwave Transmission Engineer

Consulting Experience:

1983 Keithley Instruments, Cleveland, Ohio  
1989 Failure Analysis Associates, Phoenix, Arizona  
1990 General Motors Proving Ground, Mesa, Arizona

Professional Societies and Activities:

Institute of Electrical and Electronic Engineers, Senior Member  
IEEE Transactions of Education, Member  
American Society for Engineering Education, Member  
Registered Professional Engineer in Arizona and Ohio  
Teaching Awards Committee (Schools of Const. & Tech. and SABER), Chairman  
Dean's Personnel Advisory Committee (CEAS), Member

Awards, Scholarships, and Honor Societies:

Teaching Excellence Award, College of Engineering and Applied Sciences, Arizona State University, 1988  
National Science Foundation: Science Faculty Professional Development Program (Arizona State University and Goodyear Aerospace Corporation, Tempe/Litchfield Park, Arizona), 1979-80  
National Science Foundation: National Science Faculty Fellowship (Worcester Polytechnic Institute, Worcester, MA), 1970-72  
NASA-ASEE Summer Faculty Fellowships (NASA Lewis Research Center, Cleveland, Ohio) 1970-71 Summers  
National Science Foundation, Faculty Summer Program (Worcester Polytechnic Institute, Worcester, MA), 1967,68,69 Summers  
Eta Kappa Nu, Member (past advisor)  
Tau Beta Pi, Member (past advisor)  
Tau Alpha Pi, Member (current advisor)

Principal Areas of Research or Teaching Interest:

Digital Signal Processing    Instrumentation    Communications    Microwaves

Principal Publications and Research Activities:

Maisel, J.E., "Microwave Circuit-Analysis/Amplifier-Design in Engineering Technology", ASEE Annual Conference, New Orleans, LA, 1991  
Maisel, J.E., and Young, P.H., "ACTS Phase I: Industrial/Academic Experiments", NAGW-2389, September, 1990  
Maisel, J.E., "DSP in Technology", ASEE Annual Conference, Toronto, Canada, 1990  
Maisel, J.E., "Identification of High Performance and Component Technology for Space Electrical Power Systems for Use Beyond the Year 2000", NASA Grant NAG-3-714, December, 1988  
Maisel, J.E., "A Novel Laboratory Approach for Analyzing Periodic Signals", IEEE Transaction on Education, E-31, No. 1, Feb. 1988  
Maisel, J.E., "An Average Mean Square Error Technique for Studying the Effect of Suppressing the Discrete Fourier Angle", IEEE Transactions on Education, E-30, No. 1, February 1987  
Maisel, J.E., "Maximum Power Transfer Using a Graphical Approach", Journal of Engineering Technology, Fall 1986  
Maisel, J.E., "A Historical Overview of the Electrical Power Systems in the U.S. Manned and Some U.S. Unmanned Spacecraft", NASA Grant, NAG-3-547, December, 1984  
Maisel, J.E., "Preliminary Investigation of an Electrical Network Model for Ultrasonic Scattering", NASA Contractor Report 3770 (Grant NAG362), January, 1984

## ARIZONA STATE UNIVERSITY

### GUOLIANG ZENG

Assistant Professor of Technology  
Electronics and Computer Technology,

#### Degrees:

- Ph.D. (EE), Arizona State University, 1990.
- M.N.S. (Math), Arizona State University, 1989.
- M.S. (EE), University of California at San Diego, 1982.
- B.S. (EE), Chengdu Telecommunication Institute, China.

#### Experience:

- 1991- Assistant Professor, ECT Department, ASU.
- 1987-89 Instructor, Departments of EE and Math, ASU.
- 1984-86 TA, RA, EE Department, ASU.
- 1970-80 Engineer, 966 Telephone Company, China.

#### Areas of Research/Teaching Interest:

Digital signal Processing, Probability & Statistics, Communications.

#### Publications:

- Guoliang Zeng and George Davis, "Analysis of Recursive Least Square (RLS) Algorithms for Finite Impulse Response (FIR) Filters", SIAM Conference on Applied Probability in Science & Engineering, March, 1990.
- Guoliang Zeng, "The Eigenvalue Method for the Order Determination of AR Processes", Second SIAM Conference on Linear Algebra, Nov., 1990.
- Guoliang Zeng, "A Fast and Robust Algorithm for IIR Filter", 2nd International Conference on Industrial & Applied Math., July, 1991

#### **IV. FACILITIES AND EQUIPMENT**

#### IV. FACILITIES AND EQUIPMENT

The ACTS propagation terminal will be located in the Goldwater Engineering Research Center. Specifically, the antenna will be placed on the roof with the indoor equipment located within the Telecommunications Research Center. Cable conduit exists between the roof and the Telecommunications Research Center.

The modified LBR earth terminal will be located at Motorola SED in Chandler, Arizona, which is approximately eight miles from ASU. Details of the modification have not been completed.

A \$10,000 equipment request has been included in the proposal budget for BER instruments. Type and model of the BER instruments have not been specified since this will depend, in part, on the modifications of the earth terminal at Motorola SED. However, if NASA has BER instruments that can be used with the modified LBR earth station, BER instrument purchases may not be necessary.

## **V. PROJECT BUDGET**

ESTIMATED BUDGET

PERIOD OF PERFORMANCE: August 16, 1992 - November 30, 1994

|  |                              | Year 1           | Year 2           | Year 3          | Summary          |
|--|------------------------------|------------------|------------------|-----------------|------------------|
| <b>I. SALARIES &amp; WAGES</b>             |                              |                  |                  |                 |                  |
| A. PI: Maisel                              | 25.0% AY + 50.0% summer      | \$22,773         | \$24,140         | \$5,118         | \$52,031         |
| B. Co-PI: Zeng                             | 25.0% AY + 100.0% summer     | \$25,352         | \$26,873         | \$4,069         | \$56,294         |
| C. Graduate Assistants                     | 1 @ 50.0% AY + 100.0% summer | \$13,333         | \$13,333         | \$2,667         | \$29,333         |
| D. Undergraduates                          | 1 @ 25.0% AY + 100.0% summer | \$5,460          | \$5,460          | \$780           | \$11,700         |
| E. Secretary                               | 1 @ 5.0% for 12 months       | \$791            | \$839            | \$221           | \$1,851          |
| <b>TOTAL</b>                               |                              | <b>\$67,709</b>  | <b>\$70,645</b>  | <b>\$12,855</b> | <b>\$151,209</b> |
| <b>II. FRINGE BENEFITS</b>                 |                              |                  |                  |                 |                  |
| A. Faculty at                              | 25%                          | \$12,031         | \$12,753         | \$2,297         | \$27,081         |
| B. Staff at                                | 30%                          | \$237            | \$252            | \$66            | \$555            |
| C. Students at                             | 3%                           | \$564            | \$564            | \$103           | \$1,231          |
| <b>TOTAL</b>                               |                              | <b>\$12,832</b>  | <b>\$13,569</b>  | <b>\$2,466</b>  | <b>\$28,867</b>  |
| <b>III. TRAVEL</b>                         |                              | <b>\$3,000</b>   | <b>\$3,000</b>   | <b>\$1,000</b>  | <b>\$7,000</b>   |
| <b>IV. OPERATIONS</b>                      |                              |                  |                  |                 |                  |
| A. Publication/Page Charges                |                              | \$500            | \$500            | \$500           | \$1,500          |
| B. Photocopy, telephone, postage, misc.    |                              | \$700            | \$700            | \$700           | \$2,100          |
| C. Tuition                                 |                              | \$1,654          | \$1,720          | \$894           | \$4,269          |
| <b>TOTAL</b>                               |                              | <b>\$2,854</b>   | <b>\$2,920</b>   | <b>\$2,094</b>  | <b>\$7,869</b>   |
| <b>V. CAPITAL EQUIPMENT</b>                |                              | <b>\$10,000</b>  | <b>\$0</b>       | <b>\$0</b>      | <b>\$10,000</b>  |
| <b>VI. TOTAL DIRECT COSTS</b>              |                              | <b>\$96,395</b>  | <b>\$90,134</b>  | <b>\$18,415</b> | <b>\$204,945</b> |
| <b>VII. INDIRECT COSTS = 53.5% of MTDC</b> |                              | <b>\$45,336</b>  | <b>\$47,301</b>  | <b>\$9,374</b>  | <b>\$102,011</b> |
| <b>VIII. TOTAL PROJECT COSTS</b>           |                              | <b>\$141,731</b> | <b>\$137,435</b> | <b>\$27,789</b> | <b>\$306,956</b> |