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# A Software Control System for the ACTS High-Burst-Rate Link Evaluation Terminal

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# A SOFTWARE CONTROL SYSTEM FOR THE ACTS HIGH BURST RATE

# LINK EVALUATION TERMINAL

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## SUMMARY

Control and performance monitoring of NASA's High Burst Rate Link Evaluation Terminal (HBR-LET) is accomplished by using several software control modules. Different software modules are responsible for controlling remote radiofrequency (RF) instrumentation, supporting communication between a host and remote computer, controlling the output power of the Link Evaluation Terminal and data display.

Remote commanding of microwave RF instrumentation and the LET digital ground terminal allows computer control of various experiments, including bit error rate measurements. Computer communication allows system operators to transmit and receive data from the Advanced Communications Technology Satellite. Finally, the output power control software dynamically controls the uplink output power of the terminal to compensate for signal loss due to rain fade. Included is a discussion of each software module and its applications.

## INTRODUCTION

Extensive development of a satellite communication ground station known as the High Burst Rate Link Evaluation Terminal (HBR-LET) is currently under way at the NASA Lewis Research Center. The HBR-LET will communicate with the Advanced Communications Technology Satellite (ACTS) to evaluate the performance of the Lewis-ACTS-Lewis link. Various bit error rate (BER) tests will be performed at burst rates of 110 and 220 Mbps by employing different terminal configurations to characterize the HBR-LET. (See the Appendix for a complete list of acronyms used herein.)

Users are able to control and monitor the HBR-LET with five software modules: Experiment Control and Monitor (EC&M), Check-Out, Protocol, Power Control, and Data Display. The EC&M and Check-Out modules provide a system operator or test engineer the capability to define and execute experiments by using programmable RF instrumentation within the LET. The Protocol module allows communication between two computers employing the protocol developed by General Electric (GE). Dynamic control of the traveling wave tube amplifier's (TWTA) output power to compensate for signal loss due to rain fade is performed by the Power Control Software module. The Data Display module provides both real time data displays of executing experiments and printouts and graphs of compiled data. The five software modules make up the Control and Performance Monitoring subsystem (C&PM) of the HBR-LET.

Both the EC&M and Check-Out Software modules are used to control the instrumentation on the IEEE 488 general purpose interface bus (GPIB). Multiple device control, data acquisition, instrument monitoring, and BER measurement testing are among the functions performed by the EC&M Software module. Instruments can also be individually controlled using the Check-Out Software module.

The Protocol Software module communicates with GE's Commanding, Ranging, and Telemetry Module (CR&T). Satellite configuration commands are verified by the CR&T and transmitted to the Multibeam Communications Package (MCP) on board the ACTS spacecraft. Other functions of the Protocol module include receiving from the CR&T telemetry data and event messages that occur in random bursts and sizes.

Control of the TWTA's output power is accomplished by varying the bias voltage across a pin diode altering the signal attenuation at the input of the TWTA. A rain fade algorithm determines the amount of input attenuation for the TWTA on the basis of the beacon signal strength received from the NASA Ground Station (NGS). A lookup table provides the correlation between link attenuation and the bias voltage to control the pin diode. Operations performed by the power control software include receiving the beacon signal message, decoding the message, monitoring the TWTA output power, and regulating the voltage of the pin diode power supply.

All HBR-LET software resides on a Concurrent Corporation 3205 minicomputer system utilizing Concurrent's OS/32 operating system. This paper describes each software module and its applications to the LET. Hardware design of the LET and related topics are described in separate documents to be published.

## CHECK-OUT SOFTWARE MODULE

The Check-Out Software module provides a system for experimenters to individually control and monitor the LET digital ground terminal (DGT), the data generator, data checker, and the RF instrumentation. In addition to controlling the RF instrumentation and other devices, two data acquisition commands also available allow users to read a particular instrument or group of instruments at their discretion.

Remotely controlling the RF instrumentation allows a single user to configure the entire terminal or individual subsystems to a desired state from a central location. (Various parts of the LET hardware will be housed in different areas.) Functions that can be set remotely generally include all front panel control parameters.

Individual or global data acquisition allows a user to monitor the present output or state of the instruments currently used in the terminal. By using a tablelike format, users can specify a single instrument or group of instruments from which to take data. Thus, a user can view data of several instruments simultaneously without accessing each instrument individually. The Check-Out Software module time-stamps and saves all compiled data to an external file for archiving and future analysis.

Software to control the LET-DGT uses an interactive interface to communicate with an M68000 based microcomputer. Functions of the LET-DGT software include monitoring satellite synchronization, specifying the real time burst rate, and system debugging.

One performance criterion of a communication system is the ratio of bits received in error to the total number of bits received, otherwise known as the BER. A subsystem comprised of a pseudorandom data generator, data checker, and IF Noise Unit within the LET enables users to characterize the performance of the system by measuring the BER for different $E_b/N_0$'s (ratio of energy per bit to noise density) (ref. 1). Data points for plotting a curve of the BER versus various $E_b/N_0$'s can be obtained by using the Check-Out module. A minisequence that controls the data generator, data checker, and both the signal and noise power attenuators located within the noise generation unit provides a means by which users can measure the BER over a specified range of $E_b/N_0$'s.

The values of attenuation corresponding to a specific $E_b/N_0$ are determined by using an ASCII text lookup table and are sent to the respective attenuators. Reading the BER from the data checker occurs after a user specified amount of time so that enough bits have been checked to ensure a valid BER (ref. 2). Similar measurements are made at each $E_b/N_0$ value within the defined range until all data points have been obtained. Synchronization with the satellite is monitored throughout the minisequence. Loss of synchronization can result in erroneous BER readings and possibly an error condition. All data gathered during the minisequence can be used to plot a curve of the BER versus $E_b/N_0$.

## EXPERIMENT CONTROL AND MONITOR SOFTWARE MODULE

The Experiment Control and Monitor module of the C&PM Software system is designed to allow users to set up experiments to run under computer control. This software consists of a series of programs including the Instrument Definition, the Sequence Definition, the Sequence Execution, and the Data Display. The Sequence Execution and Data Display programs use several task common blocks to track and exchange information. A task common is an area of memory which can be accessed by several programs for sharing and exchanging information. The EC&M Software also uses an in-house-developed menu display program for friendly interaction with the user. These programs form a package which allows the user to automate an experiment that may run for several hours.

An experiment is set up and executed through the following steps, as illustrated in figure 1. First, the user runs the Instrument Definition module to select and configure the set of instruments used in the experiment. This program allows the user to select the measurement and control instruments desired and to define the configuration of each instrument chosen. Information about the selected instruments is stored in the Instrument Definition File. Other data stored in this file include general control parameters for the experiment, the initial modem burst rate for the LET-DGT and instrument limit information. Limits can be applied to individual instrument parameters, such as attenuation values, power levels, BER's, and $E_b/N_0$'s. Instruments available for use in an experiment include step attenuators, frequency counters, power meters, switch drivers, and a programmable dc power supply which controls the voltage across the pin diode attenuator used in rain fade experiments. In addition to these instruments, devices such as the LET-DGT, data generator, data checker, and attenuators within the IF Noise Unit are also available. A data file stored in the computer lists all available instruments, the addresses assigned to each instrument, and information about the instrument configuration.

Second, the user runs the Sequence Definition module to select the sequence commands to execute during the experiment. This program allows the user to select a sequence of predefined commands to be executed by the computer. This program uses the information from the Instrument

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Definition File to create the commands to run the experiment. The selected commands form the Sequence Definition File. Both the Instrument and Sequence Definition Files are stored permanently so that the same experiment can be run as many times as desired without having to redefine the sequence. The Instrument Definition File must exist before defining the sequence commands for the experiment. Commands available to the user include setting parameters, incrementing parameters, checking a parameter to determine if the parameter is within user-defined limits, timing control for the experiment, looping through a set of commands within the sequence, and performing BER measurements. This program also allows the user to store groups of commands in a subsequence file. The entire group of commands can be included in a main sequence by referencing the name of the subsequence file.

Third, to perform an experiment, the Display module is run. This program automatically starts the Sequence Execution program. The multitasking capability of the computer is used so that these programs can run concurrently. Simultaneous execution of these programs allows a block of memory, a task common, to be used for the transfer of data between the programs and for the coordination of data acquisition, experiment control, and data display tasks. Information displayed to the user terminal includes the sequence number currently being executed, the instruments selected, power level readings, attenuation values, switch positions, measured $E_b/N_0$, user-defined data rates, modem burst rates, and BER measurement results. Other information that is displayed as needed includes instrument readings which fall outside of user-defined limits, system status, and any system warnings or error messages.

The Display and Sequence Execution programs use the information stored in the Instrument Definition and Sequence Definition Files to execute a test sequence with minimal user interaction. As each sequence command in the Sequence Definition File is executed, all instruments are read and the data are automatically stored in the Measurement Data File. When all sequence commands are executed, the experiment is complete. At this time the user may access the Measurement Data File as desired to produce tables or graphs from the acquired data.

The Instrument/Sequence Editor is a specialized program to allow users to easily modify the Instrument and Sequence Definition Files. This program reads the previously stored files and allows the user to change the values indicated in the sequence commands or in the instrument configurations. The user can also insert new sequence commands in the Sequence Definition File, delete sequence commands from the file, or copy existing commands.

Figure 2 illustrates the following steps to obtain data for a curve of the BER versus $E_b/N_0$:

(1)    Use the Instrument Definition module to choose the setup for each instrument used in the test.

(2)    Select two values of $E_b/N_0$, one as a starting value, the other as an ending value.

(3)    Use the Sequence Definition module to initialize the $E_b/N_0$ to the starting $E_b/N_0$ value.

(4)    Set up a loop of sequence commands to take a BER measurement. Specify the number of readings to be taken at each $E_b/N_0$. Four commands are required to take a BER measurement:

      (a)    Start the data generator with the desired data and modem burst rates.
      (b)    Wait until a sufficient amount of data have been received by the data checker.
      (c)    Read the BER from the data checker.
      (d)    Stop the data generator.

(5)    Compare the current $E_b/N_0$ value to the ending value. If the current and ending $E_b/N_0$ values differ, increment the current $E_b/N_0$ value and repeat the loop.

(6)    When the current value of $E_b/N_0$ is equal to the ending value, the test is complete.

The BER measurement data can be retrieved from the Measurement Data File and plotted to form a curve of BER versus $E_b/N_0$. The C&PM Software package provides the user with the ability to output collected data to either the user terminal or the system printer. The data are stored in ASCII format and can be transferred to any commercial software application package for further processing.

## PROTOCOL SOFTWARE MODULE

A GE-developed communication protocol (ref. 3) is used to allow the Concurrent 3205 computer and GE's CR&T to continuously transmit and receive data in real time. The C&PM Protocol Software developed at NASA meets the requirements set forth by GE. Existing protocol software was available for both a Hewlett Packard (HP) 1000 series computer utilizing the RTE-A operating system and the Digital Equipment Corporation (DEC) VAX computers running the VMS operating system. Software was not available for the Concurrent computer. Because of the machine-dependent input/output operations and procedures, new software was developed for the Concurrent computer.

The Protocol Software module consists of several programs that utilize the multitasking capability of the C&PM computer. Individual programs control the tasks of receiving, sending, processing packets, monitoring the link, and interfacing with the user. The number of packets received from GE's CR&T (telemetry data, event messages, broadcast messages, and response packets) demonstrates the need to minimize the time spent on processing by the receive program to ensure reception of all packets. Multitasking these functions (receive and process) and others allows multiple operations to be overlapped, thus minimizing the turnaround time of the receive program.

Figure 3 represents the control logic of a packet received by the C&PM computer. Once the receiving node receives and processes a data packet, it transmits the appropriate response packet back to the sending node. Other types of packets shown in the figure include response packets for data transmitted to the CR&T and communication initialization packets. Initialization packets return the state of the receiving node to a known initial condition.

The control diagram in figure 4 illustrates the flow of data packets transmitted to the CR&T from the C&PM computer. MCP commands (data packets) are retrieved from an ASCII text file, checked for correct syntax, assembled into the required format, and transmitted to the CR&T. The sending node is required to monitor the link for a response from the receiving node indicating that the packet was received. The response packet can be either a positive or negative acknowledgment, depending on the reception status of the packet. Failure to receive a positive acknowledgment response packet indicates an error condition and the packet is retransmitted. Three consecutive negative response packets indicate that the communication link is down and must be reinitialized before attempting further communication.

The software is designed to recover from a multitude of possible errors, including both telemetry reception errors (checksum, sequence counter, protocol) and command transmission errors (command destination and validity). All error handling capabilities have been tested and verified by using a test procedure developed in-house, which parallels the test procedure developed by GE for the HP and VAX software. Error recovery consists of retransmission or reinitialization in the event of repetitive errors.

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## POWER CONTROL SOFTWARE MODULE

A significant feature of the HBR-LET is the use of adaptive uplink power control to compensate for rain fade conditions. Rain is one of several factors which degrade signals transmitted between a ground station and a satellite (ref. 4). Experiments are planned to test the effectiveness of various rain fade prediction algorithms. The Power Control module is designed to allow testing of these algorithms without requiring any changes to the C&PM Software. In this design, a common block of memory is designated for the transfer of data between the Power Control module and the rain fade prediction algorithm. This allows the user to implement any desired attenuation prediction algorithm.

The beacon power levels received by the NGS are used to determine when sufficient rain occurs to require raising the power level of the uplink signal. To make this determination, the measured power levels, or beacon data, are acquired from the NGS via an RS - 422 serial communications channel. These data, consisting of two beacon signals, one each for the uplink and downlink signals, are decoded and passed to the rain fade prediction algorithm. The link attenuation predicted by the rain fade algorithm is returned to the C&PM through the same task common block and used to adjust the output power of the TWTA. These power adjustments are made by changing the bias voltage across the pin diode. This process is repeated for the duration of any rain fade event. Although beacon data are continuously received from the NGS, power adjustments to the TWTA are made only when requested by the prediction algorithm.

## SUMMARY

The High Burst Rate Link Evaluation Terminal (HBR-LET) developed at the NASA Lewis Research Center will communicate with the Advanced Communications Technology Satellite (ACTS) to perform experiments by both in-house and outside experimenters. Bit error rate (BER) measurements at burst rates of 110 and 220 Mbps will be performed to characterize the performance of the system and individual system components.

Computer control of the HBR-LET provides experimenters with several capabilities. The Experiment Control and Monitor (EC&M) and Check-Out Software modules give users the ability to configure, read, and control instrumentation within the LET. Instrument monitoring, data acquisition, and parameter control are among the functions performed by the computer during sequence execution. Satellite configuration commands can be sent to the ACTS via General Electric's Commanding, Ranging, and Telemetry module (CR&T) using the Protocol Software developed at NASA according to GE's specifications. Regulating the output uplink power of the LET's travelling wave tube amplifier (TWTA) will correct for signal degradation caused by the onset of rain fade. All data accumulated by the LET software system are made available to the experimenter in tabular and graphic formats by using both in-house and commercially available software applications.

## APPENDIX-NOMENCLATURE

ACTS      Advanced Communications Technology Satellite

ASCII      American Standard Code for Information Interchange

BER      bit error rate

| | |
|---|---|
| C&PM | Control and Performance Monitoring subsystem |
| CR&T | Commanding Ranging and Telemetry Module |
| DGT | digital ground terminal (LET) |
| $E_b/N_0$ | ratio of energy per bit to noise density |
| EC&M | Experiment Control and Monitor |
| GPIB | general purpose interface bus |
| HBR | High Burst Rate |
| IEEE | Institute of Electronic and Electrical Engineers |
| LET | Link Evaluation Terminal |
| MCP | Multibeam Communications Package |
| Mbps | megabits per second |
| NGS | NASA Ground Station |
| RTE-A | real time executive, version A |
| TWTA | traveling wave tube amplifier |
| VAX | Virtual Address Extension Machine |
| VMS | Virtual Memory System |

## REFERENCES

1.   Shalkhauser, M.J.; and Budinger J.M.:  Digitally Modulated Bit Error Rate Measurement System for Microwave Component Evaluation.  NASA TP-2912, 1989

2.   Kerczewski, R.J.; Daugherty, E.S.; and Kramarchuk, I.:  Automated Measurement of the Bit-Error Rate as a Function of Signal-to-Noise Ratio for Microwave Communications Systems.  NASA TM-89898, 1987.

3.   Tanenbaum, A., Computer Networks.  Englewood Cliffs, Prentice-Hall, 1981.

4.   Manning, R.:  A Statistical Rain Attenuation Prediction Model with Application to the Advanced Communication Technology Satellite Project.  NASA TM-100243, 1991.
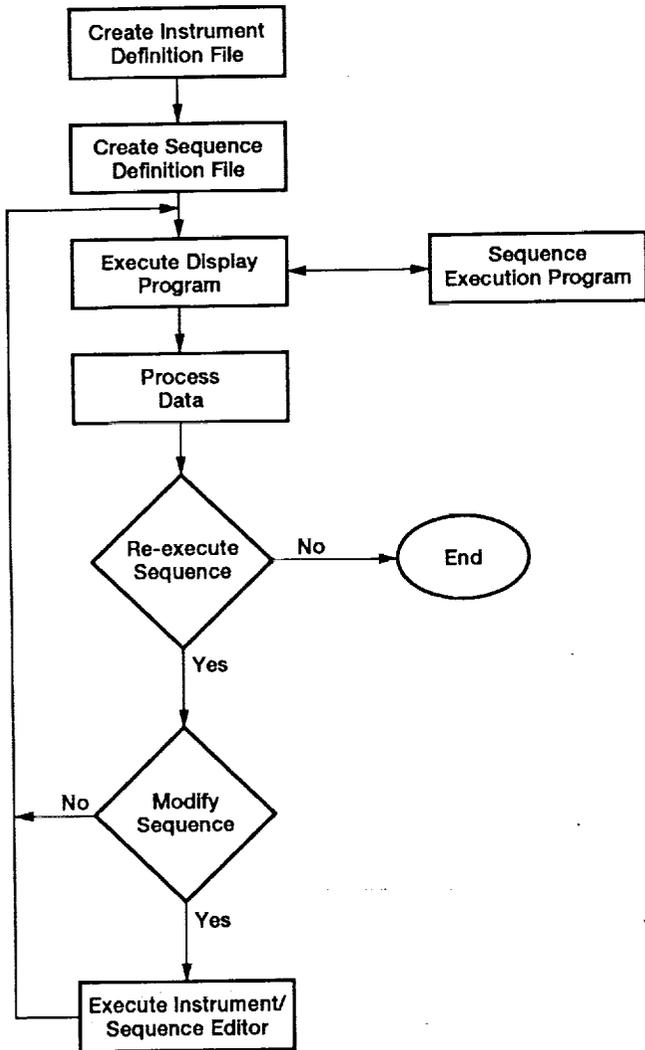
**Figure 1 flowchart:**

Create Instrument Definition File

Create Sequence Definition File

Execute Display Program ⟷ Sequence Execution Program

Process Data

Re-execute Sequence — No → End

Yes

Modify Sequence — No

Yes

Execute Instrument/ Sequence Editor

Figure 1.—Experiment definition and execution procedure.

**Figure 2 flowchart:**

Set Initial $E_b/N_0$

Start Data Generator

Wait for Data to Collect

Read Data Checker

Stop Data Generator

$E_b/N_0$ Equal to End Value — Yes → Reset Instruments to Initial Condition → End
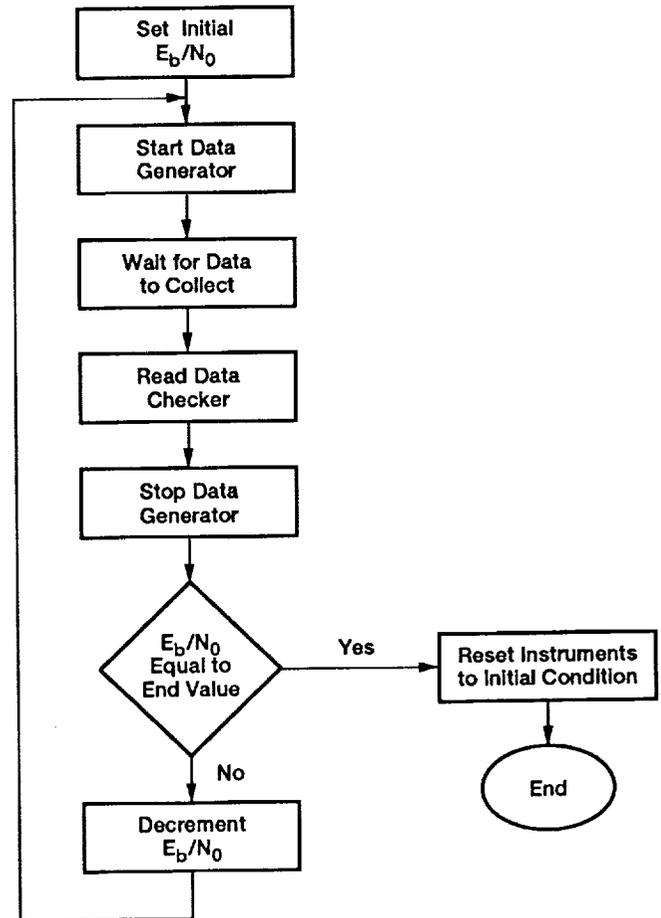
No

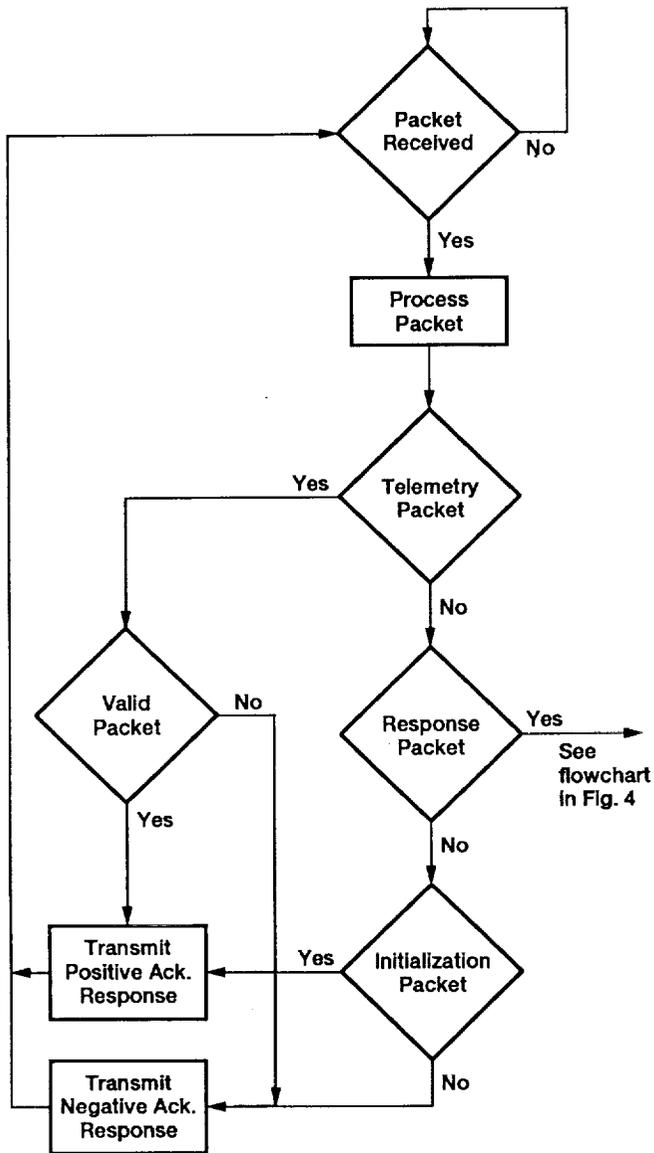Decrement $E_b/N_0$

Figure 2.—Process to generate a curve of the BER versus $E_b/N_0$.

Figure 3.—Packet reception and verification.



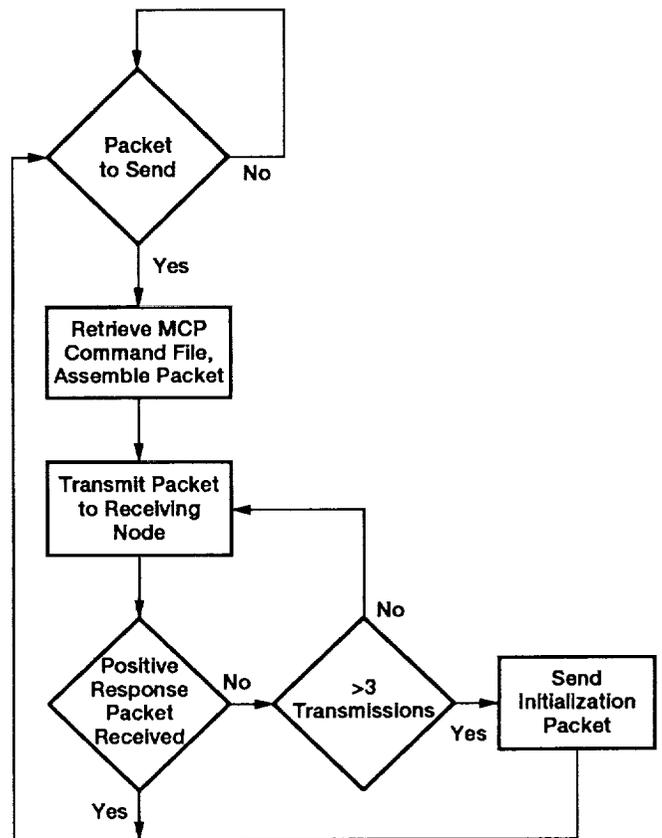Figure 4.—Packet transmission and verification.

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Control and performance monitoring of NASA's High Burst Rate Link Evaluation Terminal is accomplished by using several software control modules. Different software modules are responsible for controlling remote radiofrequency (RF) instrumentation, supporting communication between a host and remote computer, controlling the output power of the Link Evaluation Terminal (LET) and data display. Remote commanding of microwave RF instrumentation and the LET digital ground terminal allows computer control of various experiments, including bit error rate measurements. Computer communication allows system operators to transmit and receive data from the Advanced Communications Technology Satellite. Finally, the output power control software dynamically controls the uplink output power of the terminal to compensate for signal loss due to rain fade. Included is a discussion of each software module and its applications.

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