Satellite Ground–Terminal User Simulation

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SUMMARY

Realistic simulation of satellite communication systems and evaluation of satellite networking schemes require emulation of the system's users. A laboratory model of a Ka-band satellite-switched time-division multiple-access (SS-TDMA) communication network, referred to as the System Integration, Test, and Evaluation (SITE) Project, is presently under development at NASA Lewis Research Center. The SITE Project uses special bit-error-rate (BER) test sets to simulate the transmitting and receiving users of a communication network. The bit-error-rate test sets contain circuit boards that can be modified to create a variety of interfaces to satellite system ground terminals.

INTRODUCTION

In 1978, the Space Communications Division of NASA Lewis began a program to investigate the use of the Ka-band for commercial satellite communications in the United States. Through technology contracts with industry, several proof-of-concept (POC) models were developed which demonstrated the feasibility of Ka-band satellite and ground hardware. Subsequently, the SITE (System Integration, Test, and Evaluation) Project (ref. 1) was begun. Based upon a Ka-band satellite-switched time-division multiple-access (SS-TDMA) system, the SITE Project is a ground-based simulation and test bed of a satellite communication system. The facility can test and evaluate state-of-the-art satellite and ground-terminal components and subsystems, and it can also exercise and evaluate new networking algorithms.

Realistic modeling of a complete satellite system requires construction of many major components and subsystems. Many components must be as sophisticated as the actual satellite system hardware. Others, however, can be simplified depending on the complexity of the tests to be performed with the model. Several of these major components and subsystems of the TDMA communication satellite, including ground terminals and satellite transponders, are being designed and constructed at NASA Lewis for the SITE Project system. Other components used in the SITE system (receivers, switch matrices, amplifiers, etc.) are the POC models developed by industry. Some features of the satellite system must be simulated because of restrictions imposed by the laboratory environment. Range delay between the ground and the satellite, signal attenuation due to rain, and the users of the satellite system are simulated. Figure 1 shows a block diagram of the SITE Project system.

USER SIMULATION

The users and their data are important parts of a satellite communication system. Users transmit and receive data through the communication system. The

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radiofrequecy (RF) components and links of the communication system can degrade the user's data which often results in bit errors. The users need to know the degree of data degradation to determine whether to tolerate it or compensate for it. Data degradation can be quantified by using a bit-error-rate (BER) figure. A BER provides a performance measure of the RF communication links, the RF and digital subsystems, and the overall satellite communication system.

The SITE Project uses a bit-error-rate test set to simulate the communication system's users and to measure the system's effects on the user's data. The bit-error-rate test set, called the data generator and data checker (ref. 2), was designed at NASA Lewis specifically for the SITE Project. The data generator is a pseudorandom data source, and the data checker performs BER measurements. With only a slight modification to their interfaces, the data generator and data checker can simulate transmitting and receiving users, respectively. Computer control permits the data generator and data checker to simulate normal communication system user's data and operation. At the same time, the data generator and checker perform BER measurements to test the degree of data degradation imposed by the communication system.

Ground terminals interface the users to the SITE communication system. These ground terminals control the timing and the paths of the user's data transmission. Presently, each of the SITE ground terminals is capable of interfacing to three transmitting and three receiving users. The transmitting ground terminal multiplexes the data it receives from each transmitting user and bursts the data to the satellite at a high data rate. The receiving ground terminal receives the high-rate bursts and demultiplexes them so that each receiving user gets the proper data.

DESIGN

Approach

To simulate users, unique user-interface circuit boards were added to the data generator and data checker. These boards adapt the SITE ground-terminal interfaces to the data-generator and data-checker interfaces. Different user-interface boards could allow the data generator and data checker to interface to other types of ground terminals.

An important component of the SITE Project system is the controlling computer, called the experiment control and monitor (EC&M) computer. The EC&M computer controls all tests and experiments. It also controls the simulators to create different operating environments and monitors test points within the communication system to acquire operating status information.

The computer provides intelligent control of the users. The EC&M computer allows an engineer to configure various user operating parameters and to monitor their status. Based on the engineer's input, the computer selects the type of user data, the data rate, and the data destination and can control when a user enters and leaves the communication network. The EC&M computer then controls the users through the user-interface boards.

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Hardware

Data-generator user-interface board (DGUIB). - The DGUIB enables the data generator to simulate a transmitting user by interfacing the data generator to the EC&M computer and the transmitting ground terminal. The EC&M computer executes user operations through the DGUIB which creates the proper data-generator control signals. The DGUIB translates the data-generator and ground-terminal control signals so that they are compatible. Figure 2 shows the EC&M computer, the data generator, and the ground-terminal connections to the DGUIB. Figure 3 contains timing diagrams for the control signals. The operation of a transmitting user is discussed below.

The EC&M computer begins a user transmission by giving the DGUIB a $\overline{\text{RESET}}$ pulse and a selected data rate. The $\overline{\text{RESET}}$ pulse is transferred to the data generator to initialize its hardware. The data rate, selected by a 4-bit code called data rate select (DRS0-3), chooses the data-generator transmission rate. Table I shows the possible selection of data rates with their associated DRS codes.

From the $\overline{\text{RESET}}$ pulse, the DGUIB creates a request-to-send ($\overline{\text{RTS}}$) signal. The $\overline{\text{RTS}}$ and the rate-select codes are given to the ground terminal. The ground terminal checks the network for availability of transmission space for the new user's data. One of three actions will then take place:

    (1) If there is transmission space available, the ground terminal gives the DGUIB a clear-to-send ($\overline{\text{CTS}}$) signal. From the $\overline{\text{CTS}}$, the DGUIB creates a $\overline{\text{SEND}}$ pulse, which is given to the data generator to start the transmission.

    (2) If no transmission space is available, the ground terminal gives the DGUIB a request denied ($\overline{\text{RQD}}$) signal. The DGUIB responds by removing the $\overline{\text{RTS}}$ signal.

    (3) If the DGUIB receives no response from the ground terminal, it will time-out and remove the $\overline{\text{RTS}}$ signal.

The DGUIB has three signals which indicate to the EC&M computer the status of a user transmission. The $\overline{\text{CTS}}$ signal from the ground terminal is buffered by the DGUIB and then transferred to the EC&M computer. A low $\overline{\text{CTS}}$ indicates to the EC&M computer the status of the user transmission when $\overline{\text{CTS}}$ is high. When the requested transmission does not occur, DENIAL is equal to a logic 1. DENTYP, which is only valid when DENIAL = 1, indicates the type of denial: (1) when DENTYP = 1, the ground terminal denied the transmission request with a $\overline{\text{RQD}}$ signal, and (2) when DENTYP = 0, the ground terminal did not respond to the transmission request.

The EC&M computer can introduce a controlled number of errors within the data generator's data. This feature allows the EC&M to verify automatically the proper operation of the data generator, the data checker, and their interconnecting link by forcing errors and reading the BER. The EC&M gives the DGUIB an $\overline{\text{ERROR}}$ pulse and two signals (ER0, ER1). The signals, ER0 and ER1, choose which data bits to change, and the $\overline{\text{ERROR}}$ pulse creates the errors. The DGUIB buffers the three signals and sends them directly to the data generator.

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The EC&M computer can stop a data transmission by giving a $\overline{STOP}$ pulse to DGUIB, which transfers it to the data generator and causes the data transmission to terminate. The DGUIB then removes the $\overline{RTS}$ signal to the ground terminal. The ground terminal acknowledges the removal of the user from the network by removing the $\overline{CTS}$ signal. The ground terminal can stop a data transmission by raising the $\overline{CTS}$ signal to the DGUIB. The DGUIB then creates a $\overline{STOP}$ pulse to the data generator and removes the $\overline{RTS}$ signal to the ground terminal.

Data-checker user-interface board (DCUIB). - The DCUIB enables the data checker to simulate a receiving user by translating the data checker and the receiving ground-terminal control signals so that they are compatible. The DCUIB also provides an interface for the EC&M computer to read BER data and status information. Figure 4 shows the EC&M computer, the data checker, and the ground-terminal connections to the DCUIB. Figure 5 contains timing diagrams for the control signals. A discussion of the operation of a receiving user follows.

When the ground terminal has data for a receiving user, it gives a data available ($\overline{DAV}$) signal to the DCUIB. The DCUIB then creates a $\overline{RESET}$ pulse to the data checker to initialize the hardware. The DCUIB responds with an acknowledge ($\overline{ACK}$) signal to the ground terminal indicating that the receiving user is ready.

Data checking starts when the data checker receives a valid data pulse ($\overline{VDP}$), accompanied by serial data and data clock from the ground terminal. The $\overline{VDP}$ indicates the beginning of valid serial data.

Data checking is terminated by two methods: (1) The EC&M computer can terminate data checking by giving a $\overline{STOP}$ pulse to the DCUIB. The DCUIB transfers the $\overline{STOP}$ pulse to the data checker. The DCUIB then removes the $\overline{ACK}$ signal to notify the ground terminal to stop sending data. The ground terminal acknowledges by removing the $\overline{DAV}$ signal. (2) If the ground terminal can no longer give data to the data checker, it removes the $\overline{DAV}$ signal. The DCUIB gives a $\overline{STOP}$ pulse to the data checker and notifies the ground terminal by removing the $\overline{ACK}$ signal.

The DCUIB enables the receiving user to compute bit error rates. The data checker counts the number of 64-bit words received and the number of erroneous bits received. The DCUIB reads this data from the data checker and passes the data to the EC&M computer on request. The EC&M computer can then calculate the BER and present the information to the engineer. The DCUIB also performs a hardware calculation of the BER for display on the front panel of the data-checker chassis.

Computer Control

A Perkin-Elmer (PE) 3240 large minicomputer serves as the EC&M mainframe computer. Because of its size and the difficulty involved in moving it, the PE 3240 cannot always be located close to the hardware under its control. The user simulators require many parallel control lines from the EC&M computer which can be unreliable if driven long distances. As a result, a microcomputer called the EC&M interface microcomputer (EIM) is located near the data

generator and the data checker to shorten the length of the parallel signal lines. Communication between the EIM and the EC&M mainframe computer takes place through an RS-232 serial port, which can operate over a relatively long distance. The EIM then locally provides the parallel control lines to the user simulators.

A test engineer communicates to the EC&M mainframe through a terminal. The EC&M mainframe computer software, written in a high-level language called FORTRAN, allows the engineer to select the types of tests to perform. Data acquired by the computer are stored and displayed as desired. Based on the engineer's input, the EC&M mainframe sends commands to the EIM and receives status information and data.

The EIM software, written in 6809 assembly language, receives commands from the EC&M mainframe computer and performs requested operations. The EIM creates control signals to the DGUIB and the DCUIB and sends status informa- tion and data to the EC&M mainframe computer as required. Control signals from the user interface board are created through INTEL SBC 519 Programmable I/O Expansion Boards. The microcomputer communicates to the SBC 519 boards through a MULTIBUS interface. Figure 6 shows a block diagram of the EIM hard- ware configuration.

The message format of the commands between the EC&M mainframe computer and the EIM was designed to be easily readable and understandable. This mes- sage format allows a dumb terminal to be used for simulating EC&M mainframe commands. The following is a sample command showing the message format: DG1 START 1 2 0002.

All messages from the EC&M mainframe computer consist of either two or three parts. The first part is the command destination. The second part is the function to be performed. The third part, if present, is data. In the sample command shown previously, the command destination is data generator 1 (DG1); START is the function to be performed; and the data portion specifies the data rate = 1, data type = 2, and data destination = 0002.

After the engineer enters a desired test sequence at the EC&M terminal, the EC&M mainframe transmits appropriate command messages to the EIM. If a message received by the EIM is valid and error free, the message is decoded. Then the EIM gives the appropriate control signals to the data generator or the data checker. The EIM sends a message back to the EC&M mainframe to acknowledge receipt of the message. The acknowledgement is either an ACK mes- sage or a STATUS message. If a message received by the EIM is either invalid or erroneous, it sends a NAK (negative acknowledge) to the EC&M mainframe computer.

Transmitting user commands. - The EC&M mainframe computer sends four types of messages to the EIM for the transmitting users: (1) START, (2) STOP, (3) STATUS, and (4) ERROR. Table II shows the format of these messages and their acknowledgements.

The START command causes the DGUIB to reset the data-generator hardware and give an RTS signal to the transmitting ground terminal. The START command contains information that specifies the transmission data rate (DRS0-3 codes),

type, and destination. The data generator uses the data-rate code to select the correct operating clock frequency. The data type selects either simplex or duplex data. The data destination selects the destination(s) for the user's data. A user can send data to a single user, or it can broadcast its data simultaneously to as many as sixteen users. The ground terminal uses the data type and destination information to set up the proper communication paths.

The START command is acknowledged by the EIM with a STATUS command. The EIM reads three signals from the DGUIB (CTS, DENIAL, DENTYP) to determine the transmission status of the data generator. The STATUS command tells the EC&M mainframe the source of the status information and the operating status of that user. Three types of status are possible: 01, transmission started; 02, request denied; and 04, time-out occurred.

The STOP command causes the EIM to create a $\overline{STOP}$ pulse to the data generator. The EIM acknowledges the STOP command with an ACK message to the EC&M mainframe computer.

The STATUS command causes the EIM to respond to the EC&M mainframe with the transmission status of the specified user. The response is a STATUS message containing the status and data destination(s) of the user.

The ERROR command causes the EIM to create bit errors within the user's data. The number of bit errors, found in the data portion of the command, is limited to two decimal digits. This feature allows the EC&M mainframe computer to test the transmission path of a user to see if a proper connection was made. An ACK command acknowledges the ERROR command.

Receiving user commands. - The EC&M mainframe computer sends three types of messages to the EIM for the receiving users: (1) STATUS, (2) STOP, and (3) BER. Table II shows the format of these messages.

The STATUS command causes the EIM to check the receive status of the specified user. The response from the EIM to the EC&M mainframe is a STATUS command containing the source user indentifier and the status of the receiving user.

The STOP command causes the EIM to create a $\overline{STOP}$ pulse to the DCUIB. The EIM acknowledges the STOP command with an ACK message to the EC&M. The BER command causes the EIM to gather bit-error-rate data from the DCUIB. The EIM inputs the BER data by giving the DCUIB a series of control signals. First, the EIM gives a transfer pulse ($\overline{TRANS}$) to the DCUIB. Then the BER data, the total number of words received, and the number of bits received in error are transferred from the data checker to the DCUIB. The DCUIB allows the EIM to read 16-BER data bits at a time. When given a 3-bit register select code (RSO-2) from the EIM, the DCUIB transfers a selected 16-bit grouping to a register that the EIM can read. The EIM transfers the BER data to the EC&M mainframe in a BER message.

Upon receiving the first character of a message from EC&M mainframe computer, the EIM creates an interrupt. The interrupt service routine inputs the whole message, a character at a time, and stores it in a character buffer. A carriage return signals the end of a message. When a complete message is

received, the program first determines if the message is for a data generator or a data checker. Then the user number (1, 2, or 3) is read and stored in a flag. Next, the command type is determined by comparing the command in the character buffer to acceptable stored messages. If an invalid message is received, the EIM immediately sends a NAK message to the EC&M mainframe. When the type of message is determined, the program jumps to an appropriate subroutine to perform the required operation. Figure 7 contains a high-level flowchart of the 6809 microcomputer software.

CONCLUDING REMARKS

Simulation of a Ka-band satellite-switched time-division multiple-access satellite system requires realistic simulation of satellite system users. The System Integration, Test, and Evaluation (SITE) Project of NASA Lewis adapted a bit-error-rate (BER) measurement system, called the data generator and data checker, for this purpose. The BER measurement system enabled the SITE Project to simulate realistic user data and also to test the effects of the satellite system on the data. The BER measurement system was modified to simulate a transmitting and receiving user by the addition of user-interface boards to the existing data-generator and data-checker hardware. A computer was used to control user operations automatically. This approach provided flexibility for creating several different types of user interfaces using the same BER test set.

APPENDIX - SYMBOLS

Figures 2 and 4 contain a number of symbols which are defined as follows:

$\overline{\text{ACK}}$	acknowledge
$\overline{\text{CTS}}$	clear-to-send
DATA	BER data in 8-bit output register
$\overline{\text{DAV}}$	data available
DENIAL	transmission request was denied
DENTYP	type of transmission; 1 = transmission denied by ground terminal, 0 = time-out
DRS	data rate select code
$\overline{\text{ERROR}}$	pulse to force errors within data
ER0, ER1	bit to create error in
$\overline{\text{NAK}}$	negative acknowledge
$\overline{\text{RESET}}$	pulse to initialize hardware
$\overline{\text{RQD}}$	request denied
RS0, RS1, RS2	register select
$\overline{\text{RTS}}$	request to send
$\overline{\text{SEND}}$	pulse to begin data transmission
$\overline{\text{STOP}}$	pulse to stop hardware
$\overline{\text{TRANS}}$	pulse to transfer BER data to output register
$\overline{\text{VDP}}$	valid data pulse

REFERENCES

1. Bagwell, J.W.: A System for the Simulation and Evaluation of Satellite Communication Networks. AIAA 10th Communication Satellite Systems Conference, AIAA, 1984, pp. 172-180. (NASA TM-83531).

2. Windmiller, M.J.: Unique Bit-Error-Rate Measurement System for Satellite Communication Systems. NASA TP-2699, 1987.

TABLE I. - USER DATA RATES

Data rate, select code (Hex)	Rate, MHz	Description
0	1.25	General purpose
1	1.544	T1 Telecommunications rate
2	N/A	N/A
3	5.00	General purpose
4	6.132	T2 Telecommunications rate
5	12.5	General purpose
6	16.1079	Digital video
7	N/A	N/A
8	25.0	General purpose
9	N/A	N/A
A	42.95	Digital video
B	44.736	T3 Telecommunications rate
C	50.0	General purpose
D	100.0	General purpose
E	N/A	N/A
F	200.0 (or variable)	General purpose

TABLE II. - MESSAGE FORMAT[a]

[Each character on chart represents one ascii character.]

	Message	Acknowledgement
Data Generator	DGx STOP DGx START r y dddd DGx ERROR ee DGx STATUS	ACK ECM DGx STATUS uuuuuuut ACK ECM DGx STATUS uuusdddd
Data Checker	DCx STOP DCx STATUS DCx BER	ACK ECM DCx STATUS uuusuuuu ECM DCx BER uuwwwwwwwwwweeeeeeee

[a]Symbols used herein:
   d destination   t transmission status-
   e bit in error   1 transmission started
   r rate   2 transmission denied
   s status-   4 time-out
      1 active   u unused
      0 inactive   w words received
                           x user number
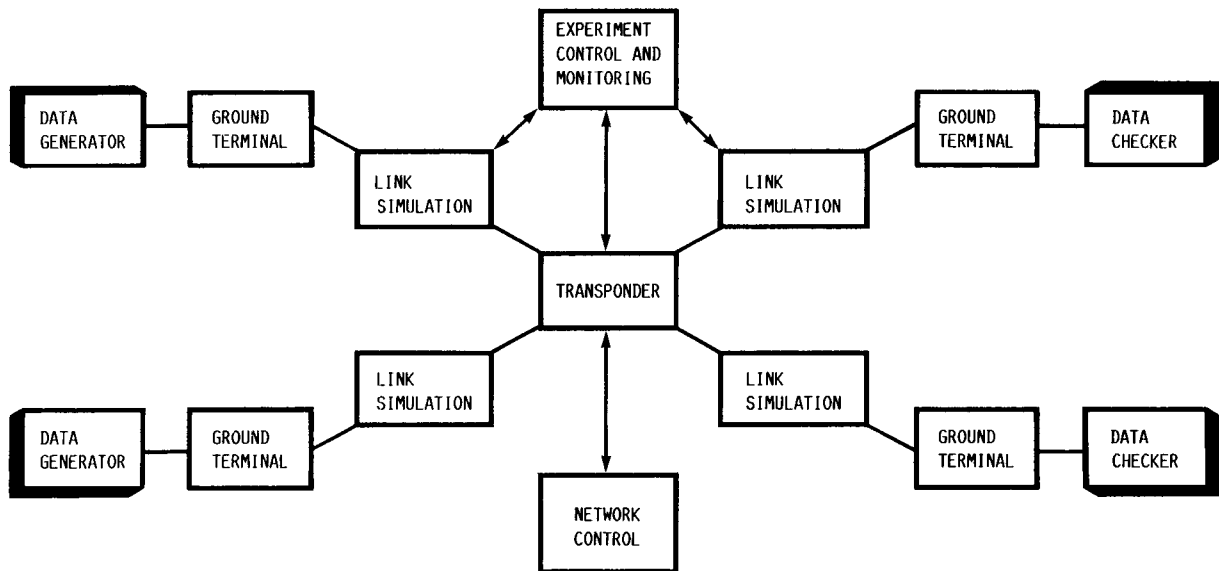   y data type

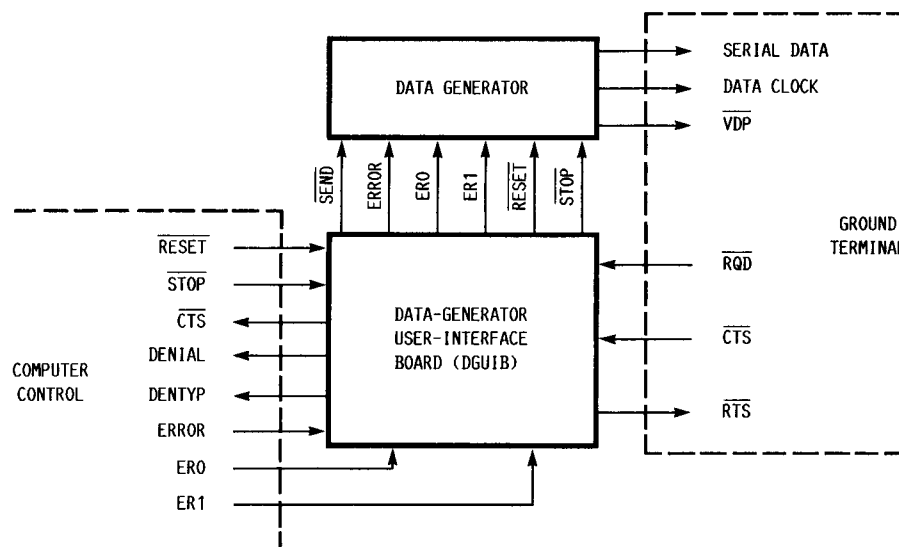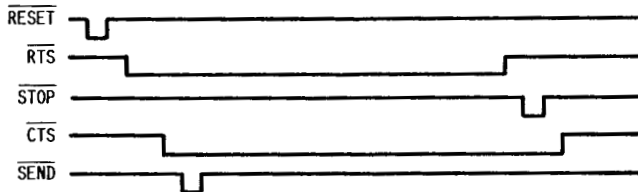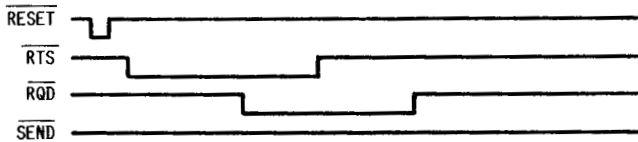FIGURE 1. – SITE PROJECT BLOCK DIAGRAM.

FIGURE 2. – DATA-GENERATOR USER-INTERFACE BOARD AND INTERFACES. (SEE APPENDIX FOR SYMBOL DEFINITION.)
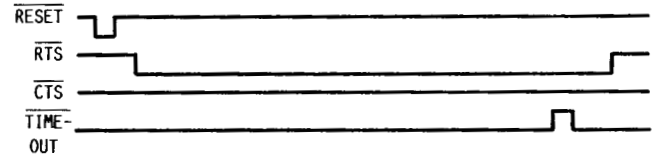
(1) USER STARTS AND STOPS A TRANSMISSION.

RESET
RTS
STOP
CTS
SEND

(3) A TIME-OUT OCCURS ON A REQUEST.

RESET
RTS
CTS
TIME-
OUT

(2) GROUND TERMINAL DENIED A TRANSMISSION REQUEST.

RESET
RTS
RQD
SEND

(4) GROUND TERMINAL TERMINATES THE TRANSMISSION.

RESET
RTS
CTS
SEND
STOP
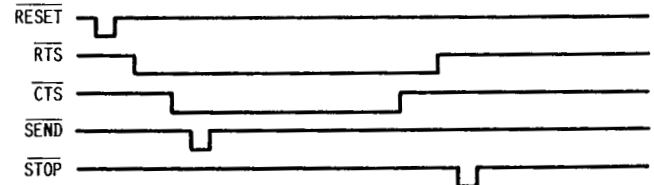
FIGURE 3. - DATA-GENERATOR USER-INTERFACE-BOARD TIMING.
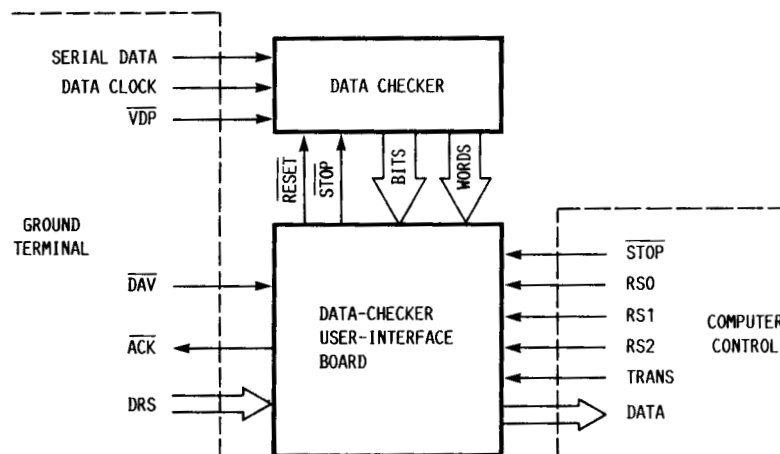
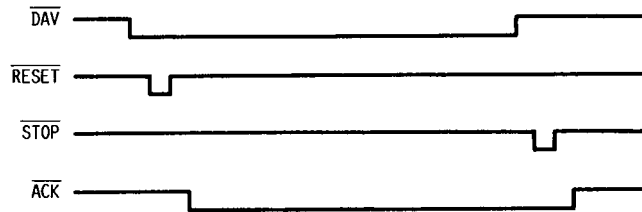FIGURE 4. - DATA-CHECKER USER-INTERFACE BOARD AND INTERFACES. (SEE APPENDIX FOR SYMBOL DEFINITION.)

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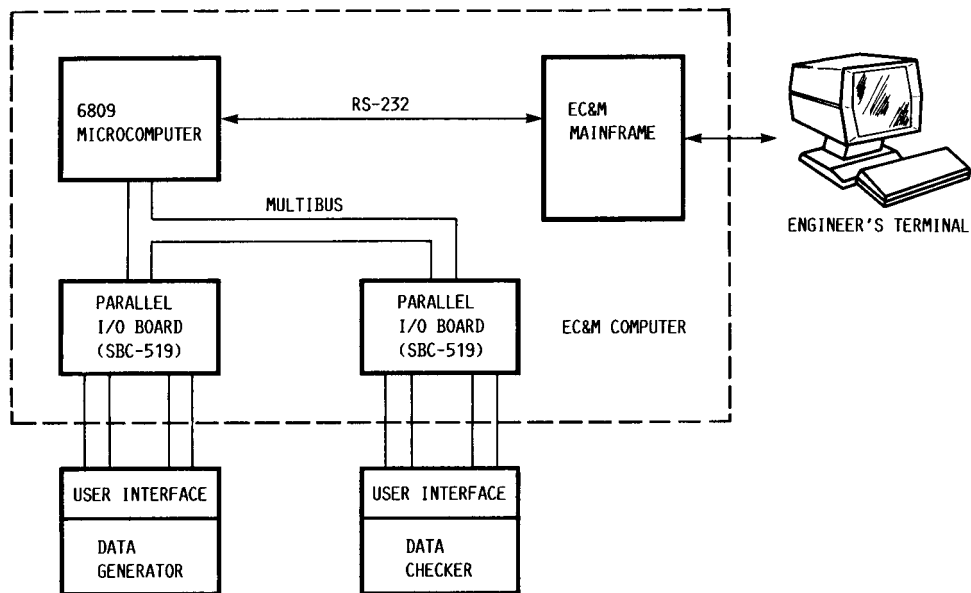FIGURE 5. - DATA-CHECKER USER-INTERFACE-BOARD TIMING.

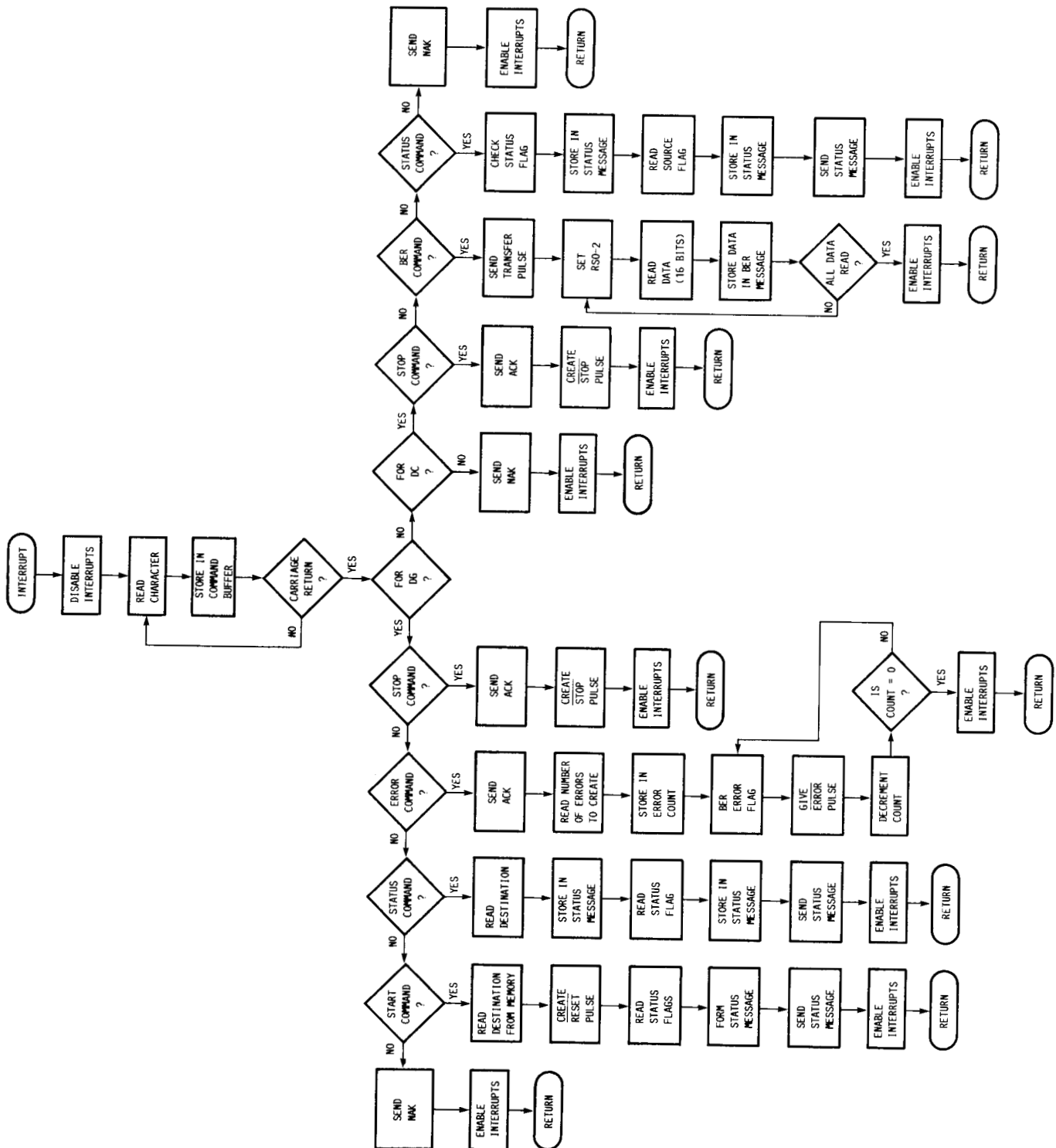FIGURE 6. - COMPUTER CONTROL CONFIGURATION.

FIGURE 7. – USER-INTERFACE CONTROLLER FLOW CHART.

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15. Supplementary Notes

16. Abstract

Realistic simulation of satellite communication systems and evaluation of satellite networking schemes require emulation of the system's users. A laboratory model of a Ka-band satellite-switched time-division multiple-access (SS-TDMA) communication network, referred to as the System Integration, Test, and Evaluation (SITE) Project, is presently under development at NASA Lewis Research Center. The SITE Project uses special bit-error-rate (BER) test sets to simulate the transmitting and receiving users of a communication network. The bit-error-rate test sets contain circuit boards that can be modified to create a variety of interfaces to satellite system ground terminals.

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