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RF COMMAND AND RANGING SYSTEM FOR BALLOON FLIGHT APPLICATIONS.(U)
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RF COMMAND AND RANGING SYSTEM FOR BALLOON FLIGHT APPLICATIONS

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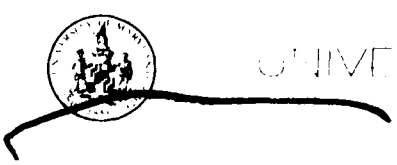

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This paper describes a radio frequency (RF) command and ranging system developed to provide the scientific balloon community and other users with a versatile, self-contained system for remote control applications. Emphasis has been placed on limiting the weight, size, and cost of the remote unit in order to make the system economical in applications where recovery is not practical. The design incorporates several unique features which allow for expanding the degree of sophistication obtainable in balloon command and

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Block 20 Abstract (continued)

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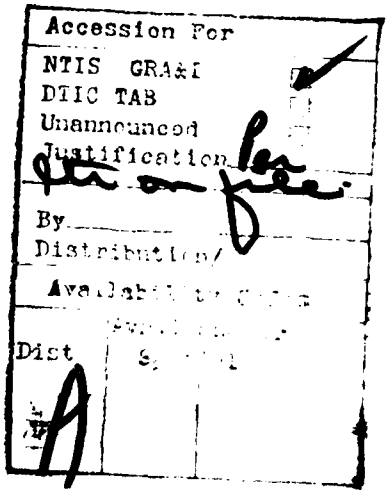

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ABSTRACT

This paper describes a radio frequency (RF) command and ranging system developed to provide the scientific balloon community and other users with a versatile, self-contained system for remote control applications. Emphasis has been placed on limiting the weight, size, and cost of the remote unit in order to make the system economical in applications where recovery is not practical. The design incorporates several unique features which allow for expanding the degree of sophistication obtainable in balloon command and control. Upon command, the base station transmits a self-clocking, pulse code modulated signal and receives a status signal reply from the remote unit. The base station and remote unit operate in simplex mode utilizing the same carrier frequency for both transmission and reception. The system provides slant range accurate to ± 3 nautical miles, command and status of 15 independent channels, and flight termination control. Successful flight tests have been performed in New Mexico and Antarctica.

I. Introduction

Air safety regulations require that unmanned free balloons be capable of termination upon command. Often, it is important to know the location of the balloon, either to facilitate the recovery of a payload when dropped or to describe measurements with respect to a fixed coordinate frame. Independent tracking facilities are not always available. Furthermore, in many applications it is necessary or desirable to exercise control over other balloon and payload functions (e.g., ballast drops, gain changes). All of the capabilities mentioned above may be required in some cases.

Many devices available to the user of small balloons omit one or more important features or are unacceptable for a variety of reasons (e.g., weight, cost, power consumption, complexity). The present design overcomes these disadvantages. The following sections describe the principal controls and features, the theory of operation, and the results of several flight tests. A summary of the system specifications is given in Table I.

II. Controls and Features

The RF command and ranging system consists of a base station and remote unit. Special attention has been given to simplifying the operation of the system by implementing unambiguous operator controls and display features. Further simplification has been achieved by eliminating any requirement for the user to perform equipment adjustment or pre-flight alignment procedures.

The base station (Figures 1 and 2) contains a transmitter, receiver, digital coding and logic circuitry, and power supply that operates from either a 110 volt, 60 Hz ac line or a 12 volt dc automotive battery. The front panel (Figure 1) displays slant range in nautical miles, flight elapsed time, and the status of 15 independent channels, flight termination circuitry, and

battery voltage in the remote flight unit. Manual or automatic monitoring of the range, channel selection and command, and flight termination are controlled by front panel switches. A four-level unit code, manually set by a switch on the rear panel (Figure 2) permits a single base station to control up to four flight units in the same RF environment.

The remote unit (Figures 3 and 4) contains a transmitter, receiver, digital coding and logic circuitry, battery board, and dipole antenna. The weight of the entire remote package, including dipole antenna and sufficient batteries (lithium cells) for a nominal 100 hours flight, is 6 pounds.

Base Station

Range. The RANGE section consists of a range display and an update switch. The slant range distance from the base station to the remote unit is measured in nautical miles and displayed by a three digit (0-999) Liquid Crystal Display (LCD). The range command is provided to permit obtaining distance information without the need to send a channel (tasking) command. The range UPDATE switch is provided with three positions, MAN, AUTO, and HOLD. The MAN (manual) position is a momentary switch position that initiates a range command and automatically updates the range display. The AUTO (automatic) position automatically requests and displays range information every 30 minutes. The HOLD position inhibits the AUTO mode of operation.

Command. The COMMAND section consists of a 15-position command SELECT thumbwheel switch, a SEND switch and a 4-position UNIT CODE Light Emitting Diode (LED) display. The fifteen select positions provide independent on/off control of fifteen channels (flip-flop gates) in the remote unit. Commands can be sent one at a time in any order and as many times as desired. Successive commands sent on the same channel toggles the gate between off and on.

In the off state, a low voltage is present at the gate output of the given channel; in the on state the gate output is at high voltage (8 volts). A channel command is sent by selecting the desired channel on the Select switch and holding the Send switch up for approximately three seconds. The system will automatically send the command and update the displays. The Unit Code display indicates which one of the four permissible codes has been selected for the system. A switch located on the chassis rear panel (Figure 2) selects the Unit Code. The Unit Code feature permits operating up to four remote units at the same time in the same RF environment.

Cut Down Control. The CUT DOWN CONTROL consists of a covered command switch and three LED displays (REC, FIRE VOLTS and FIRED). The Cut Down Control switch sends a command to fire a squib located in the remote unit (Figure 3). The REC (command received) and FIRE VOLTS LEDs, initially green, turn red when the Cut Down command is received and the voltage to fire the squib is applied. The FIRED LED, initially green, turns red to indicate that the squib has fired and severed a line fed through the squib.

Remote Status. The command channel and LOW BAT (low battery voltage) status of the remote unit is displayed by LEDs. Initially, the LEDs are green to indicate all channel commands are off and the battery voltage condition in the remote unit is good. Individual channel LEDs alternately toggle between green and red successively as channel commands are sent and a reply is received from the remote unit. The LOW BAT LED turns red when the battery voltage in the remote unit drops below a fixed voltage level.

It is emphasized that the Remote Status displays are derived by decoding the reply signal received from the remote unit and not from commands sent by the base station.

Elapsed Time. The ELAPSED TIME section consists of a four-digit LCD and a three position CLOCK switch (ADV, RUN and RESET). The Elapsed Time LCDs indicate the time duration of the flight in units of hours and minutes up to 100 hours before "rolling-over". The first command sent by the base station or received from the remote unit starts the elapsed time counter and enables a one second colon blinker located between the hours and minutes digits (to indicate time has started). With the switch in the ADV (advance) position, time is advanced at a rate of about one minute per second to permit pre-setting the clock. Placing the switch in the RUN position allows the clock to operate normally; in the RESET position the time is reset to zero.

Transmit Signal. The TRANSMIT SIGNAL LED turns red during the base station transmit time (approximately 0.6 seconds) to indicate that a signal is being transmitted.

Received Signal Strength. The relative received signal strength of the remote unit is displayed on a panel meter. A meter reading above mid scale is adequate for reliable operation.

Receiver Video. The receiver video is provided on the chassis rear panel to permit the operator to view the relative quality of the received signal from the remote unit and to more clearly see the type and degree of any co-channel interference, if present.

Range Voltage. The slant range distance data displayed on the front panel is fed to a Digital-to-Analog Converter (DAC) to provide a dc voltage (available on the chassis rear panel) for output to a recorder.

Operator Alert. In the event the return signal from the remote unit is interfered with, or for any other reason the base station is prevented from receiving this signal, the range display will blink continuously, retaining the last valid range information in the display. A buzzer will also sound for about 3 seconds (instead of the normal 1.2 seconds for each transmission) to alert the operator. Receipt of a good quality signal from the remote unit automatically updates the range and status displays and stops the range display from blinking.

Remote Unit

Control Switch. The control switch has three positions, FLY, OFF and TEST (Figure 4). Battery power is applied to the unit in both the FLY and TEST positions. In both positions, the unit responds to commands from the base station. However, in the test mode the squib can be tested but not fired. Upon turn-on, the remote unit transmits a status signal to remotely start the Elapsed Time clock in the base station. Power is removed from the circuitry in the OFF position.

Unit Code. A Unit Code thumbwheel switch is located on the front edge of the logic board (Figure 3) in the remote unit. This switch must be set to the same 1 through 4 unit code position as set in the base station.

LED Indicators. Three LEDs indicate the unit's operational status. A power LED blinks once every two seconds when the unit is in the FLY or TEST mode. A transmit LED lights when the unit is transmitting a status report to the base station. A squib test LED lights when the squib is "fired" in the test mode. This test reveals that a low test current has flowed through the squib.

Command Channel Output Connector. A 25 pin, type D, connector provides fifteen output command channels with switched on/off capability for equipment control. The channel drivers are CMOS logic gates with a series 20K ohm resistor to prevent shorting the logic.

III. Theory of Operation

Operation of the system is based upon transmitting a 0.6 second duration, frequency modulated (FM), pulse code modulated (PCM), 16-bit encoded, self-clocking command signal from the base station to the remote unit and receiving a 2.4 second duration, 32-bit, status signal reply (similarly modulated) from the remote unit approximately 1.3 seconds later. Twenty-one unique codes are encoded in the command signal. These include 15 channel commands, one range command, one squib fire command, and two unit code bits. Four unit codes and nineteen status bits are contained in the reply signal from the remote unit. Status information is provided for the 15 command channels, 3 squib monitors, and the good/weak condition of the remote unit battery power. Slant range distance information is obtained by accurately measuring the time delay between transmission of the command signal and reception of the status signal. Simplex operation provides transmission and reception utilizing the same frequency. The major operations performed within the base station and the remote unit are as follows:

Base Station

A functional block diagram for the base station is shown in Figure 5. The operation is begun by setting the same Unit Code in the base station as set in the remote unit, and sending a Range, Channel command or a Cut-Down command to the remote unit.

Upon initiating the command, the encoding transmit function generator circuitry sequentially develops the proper code to be sent by sensing the control switch settings. This circuitry also switches the TX/RX antenna relay to the TX position, enables the transmitter for approximately 0.6 seconds, and enables a nautical mile (NM) range counter to measure the distance between the remote unit and the base station. It also controls a buzzer and blinking of the range display to aurally and visually notify the operator that a command is being sent. The enabled range counter continuously increments through counts of 0 to 1000 NM until it is stopped at the proper count by a pulse generated in the decode and error checking circuitry. This pulse is derived from the reply signal transmitted by the remote unit. Additionally, this pulse transfers the range information into the storage gates and stops the buzzer and the range display from blinking. Range data from the storage gates is displayed on the front panel and also fed to a digital-to-analog voltage for output to a recorder.

In the event a reply signal is not received from the remote unit, the original range data are retained in the storage gates, the range display continues to blink and the buzzer operation is extended from the normal period of 1.2 seconds to about 3 seconds. Under this condition, the normal procedure is to send a range command. Upon receipt of a good signal, the base station will automatically update the range display, stop the display from blinking and sound a normal length buzz.

The signal from the remote unit is fed through the base station's Band Pass Filter (BPF) and TX/RX relay into the receiver where it is demodulated. After demodulation, the signal is fed to a comparator where it is converted into a binary digital signal for digital processing. Prior to being demodulated,

the signal is also fed to a receiver signal conditioning circuit where it is amplified, low-pass filtered, and sent to a signal strength meter to indicate the relative signal strength. The digital signal from the comparator is clocked into a 32-stage shift register for processing by the decode and error checking circuitry. A properly decoded signal generates a pulse that performs the operations discussed above along with storing the status data content of the shift register into the status storage gates for display on the front panel by red/green LEDs.

An Elapsed Time circuit measures and displays the time duration of the balloon flight up to a maximum of 100 hours before "rolling over". This circuit is enabled upon transmitting a command from the base station or upon receipt of a signal from the remote unit. Switch control is provided to reset or to advance the elapsed time circuitry to a preset value. Additionally, the elapsed time circuit generates a pulse every 30 minutes that is used by the range command circuit, in the AUTO mode, to automatically request status reports from the remote unit. This feature along with the range DAC output voltage permits automatically recording the remote unit's range on a recorder.

Remote Unit

A functional block diagram of the remote unit is shown in Figure 6. The remote unit is operated in one of two modes, FLY or TEST, and in one of four Unit Code identification positions. Operation in both modes is identical, except that in the TEST mode the squib fire current is limited to well below the fire level. Normally, the remote unit is operating in the receive position with the same Unit Code setting as in the base station, awaiting a command.

The signal from the base station is fed from the dipole antenna through the input BPF and TX/RX relay into the receiver where it is demodulated. After demodulation the signal is fed to a comparator, where it is converted into a binary digital signal and clocked into a 16-stage shift register for processing by the decode and error checking circuitry. A properly decoded channel or cut down command generates a pulse that toggles the appropriate command flip-flop gate and also initiates a retransmit operation. A properly decoded range command also initiates the retransmit operation but does not toggle a flip-flop. The function generator generates the proper coded signal for transmission, switches the TX/RX antenna relay to the TX position and enables the transmitter for approximately 2.4 seconds to send the status of the remote unit.

The reported status consists of the on/off state of fifteen command channel flip-flops, the Cut Down channel flip-flop on/off state, the squib FIRE Volts and FIRED status, the LOW BAT sense state and the Unit Code selected. The flip-flops toggle (change on/off state) on consecutive commands. Squib Fire Volts and FIRED sense circuits indicate that voltage was applied to the squib and the squib fired. The LOW BAT sense circuit indicates that the remote unit's battery power has decreased below a desired value and the balloon flight should be terminated shortly. Three monitor LEDs are provided on the remote unit's control panel to indicate during pre-flight tests when a transmission occurs, when the dc power is on, and when the squib fire circuit is activated in the test mode.

IV. Flight Tests

To date, successful flight tests have been performed from New Mexico and Antarctica on prototype versions of the system described. The principal difference between the prototype and current versions of this system is in the unit code feature (the prototype system has only a single code capability). The current version is undergoing testing at NASA's Wallops Island facility.

Figures 7 and 8 illustrate range data obtained during the New Mexico and Antarctic tests. In the New Mexico test (Figure 7) two units, designated prototype and production models, were flown from the same balloon to demonstrate repeatability of the range measurements. This test demonstrated the system's capability to provide slant range distance to an accuracy within the measurement capability of the independent tracking radar (< 2 NM) as well as verifying the performance of all other features of the system.

No independent range verification was possible for the Antarctic flight test (Figure 8). The data are presented to illustrate the consistency of the measurements for a much longer duration flight, and the greater range apparently reached. The data on the balloon bearing was obtained from the strength of a telemetry signal, not from the command/range system. Other flights in the Antarctic series gave similarly consistent results.

V. Acknowledgements

Funding for the design and development of the RF Command and Ranging System has been provided by the Office of Naval Research under contracts N00014-77-C-0423 and N00014-81-K-0153 to the University of Maryland. DACOM Corporation is a subcontractor of the University of Maryland. Useful suggestions have been contributed by Dr. D.L. Matthews, Dr. J.C. Siren, and Mr. L. Lutz of the University of Maryland, and by Mr. W. Cross of the Office of Naval Research.

Table I System Specifications

	Base Station	Remote Unit
Operational Commands	15 unique "ON/OFF"	15 unique "ON/OFF'
Terminate Command	1, dedicated to squib firing	1, dedicated to squib firing
Range Command	1, updates remote unit range and command status display at base station	1
Receiver Bandwidth	20 kHz at 12 dB bandwidth nominal	7 kHz at 6 dB bandwidth nominal
Frequency	138.54 MHz, simplex operation	138.54 MHz, simplex operation
Frequency Stability	10 ppm nominal	20 ppm
Modulation	FM (30F9)	FM (30F9)
Transmitter Power	10 watts nominal	1 watt nominal
Transmitter and spurious harmonics	40 dBc minimum	40 dBc minimum
Transmit time	0.6 seconds	2.4 seconds nominal
Temperature Range	0°C to +50°C	-40°C to +50°C, inside
Power	115 VAC or 12-15 VDC at 3 amp peak current	10-15 V @ 30 ma (receive) 10-15 V @280 ma (transmit), 6 V @ 5 amps to fire squib
Housing	Portable chassis 16"x7"x17"	Styrofoam box, approx. 11" cube; outside
Weight	25 lbs.	6 lbs. nominal, includes housing, antenna and batteries (7 ea. Lithium "D" cells)
Antenna	YAGI, 9 dB gain nominal	Dipole
Range Accuracy	±3 nautical miles nominal	
Range Distance	Approx. 400 NM for 100,000 ft. limited by line-of-sight.	
Elapsed Time Display	100 hours	

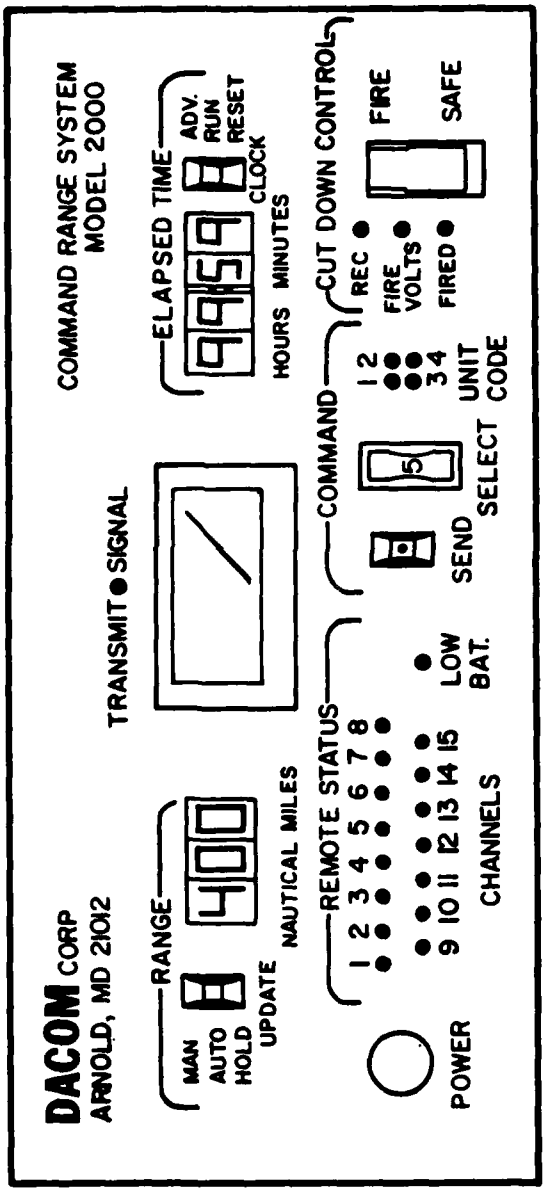

FIG. 1 BASE STATION CONSOLE-FRONT PANEL

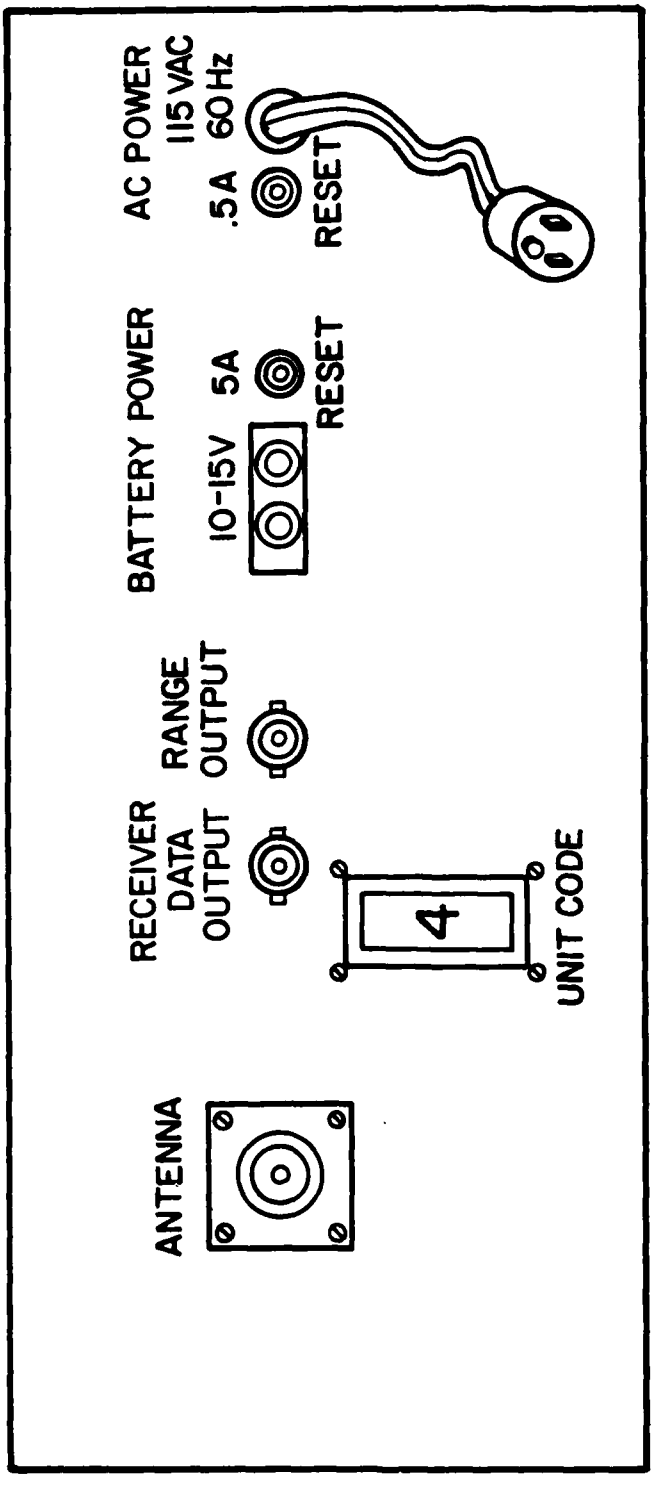

FIG. 2 BASE STATION CONSOLE—REAR PANEL

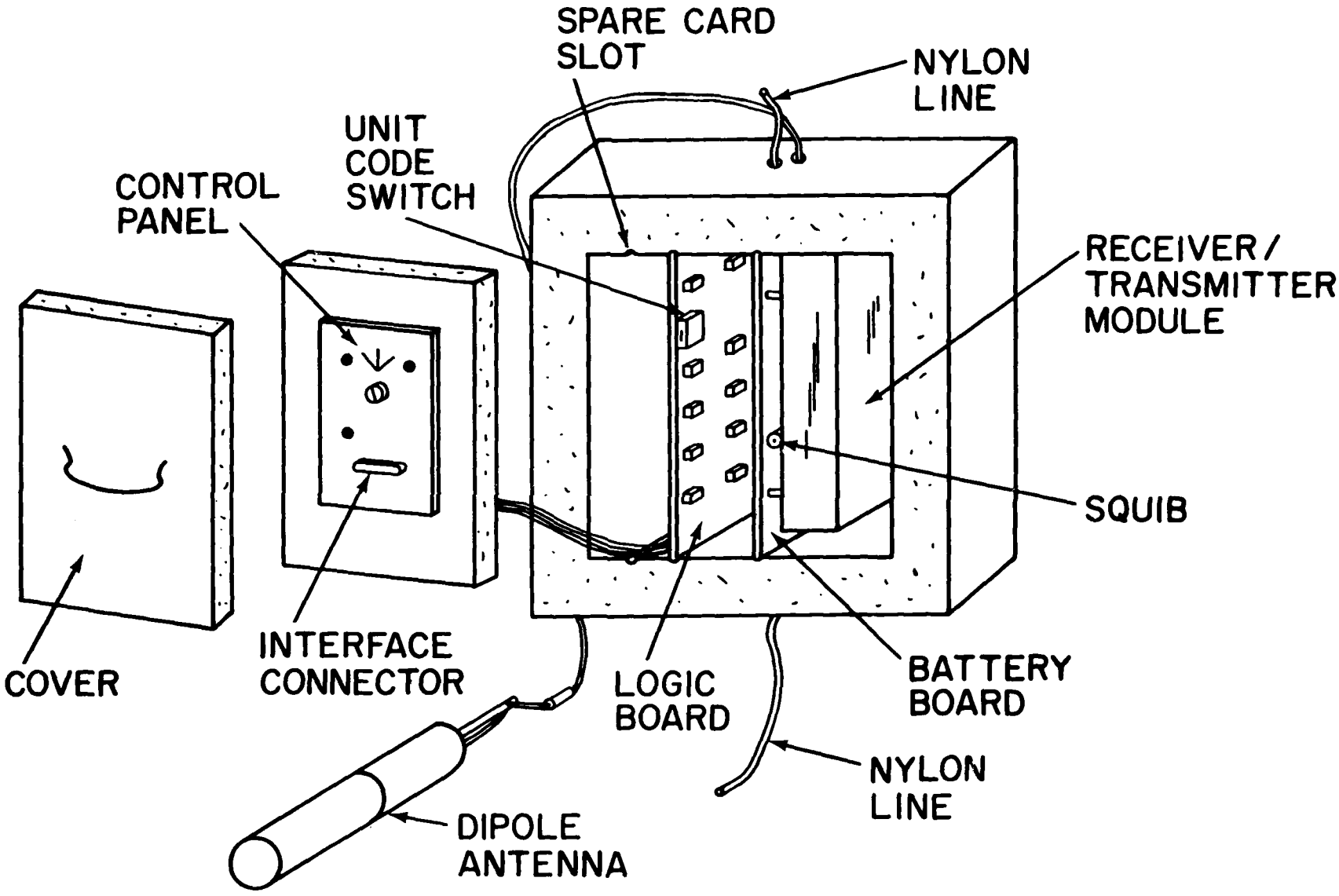

FIG. 3 REMOTE UNIT

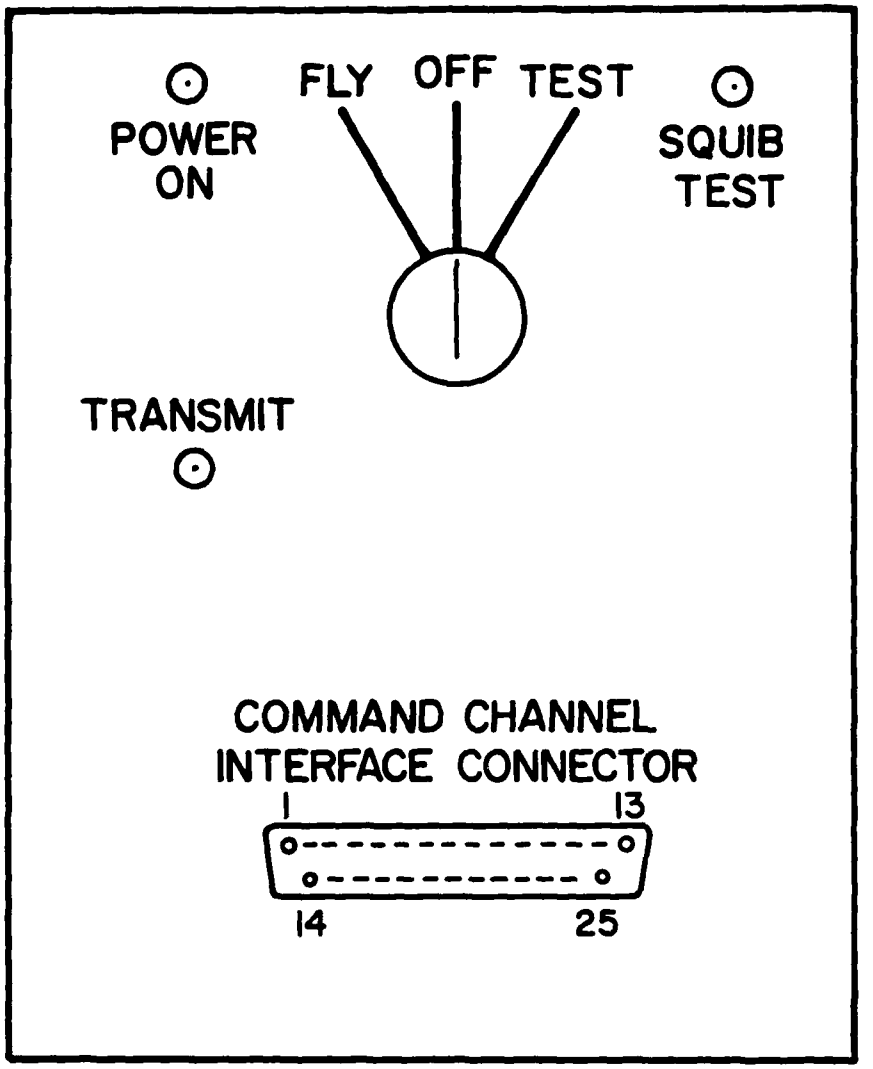

FIG. 4 REMOTE UNIT CONTROL PANEL

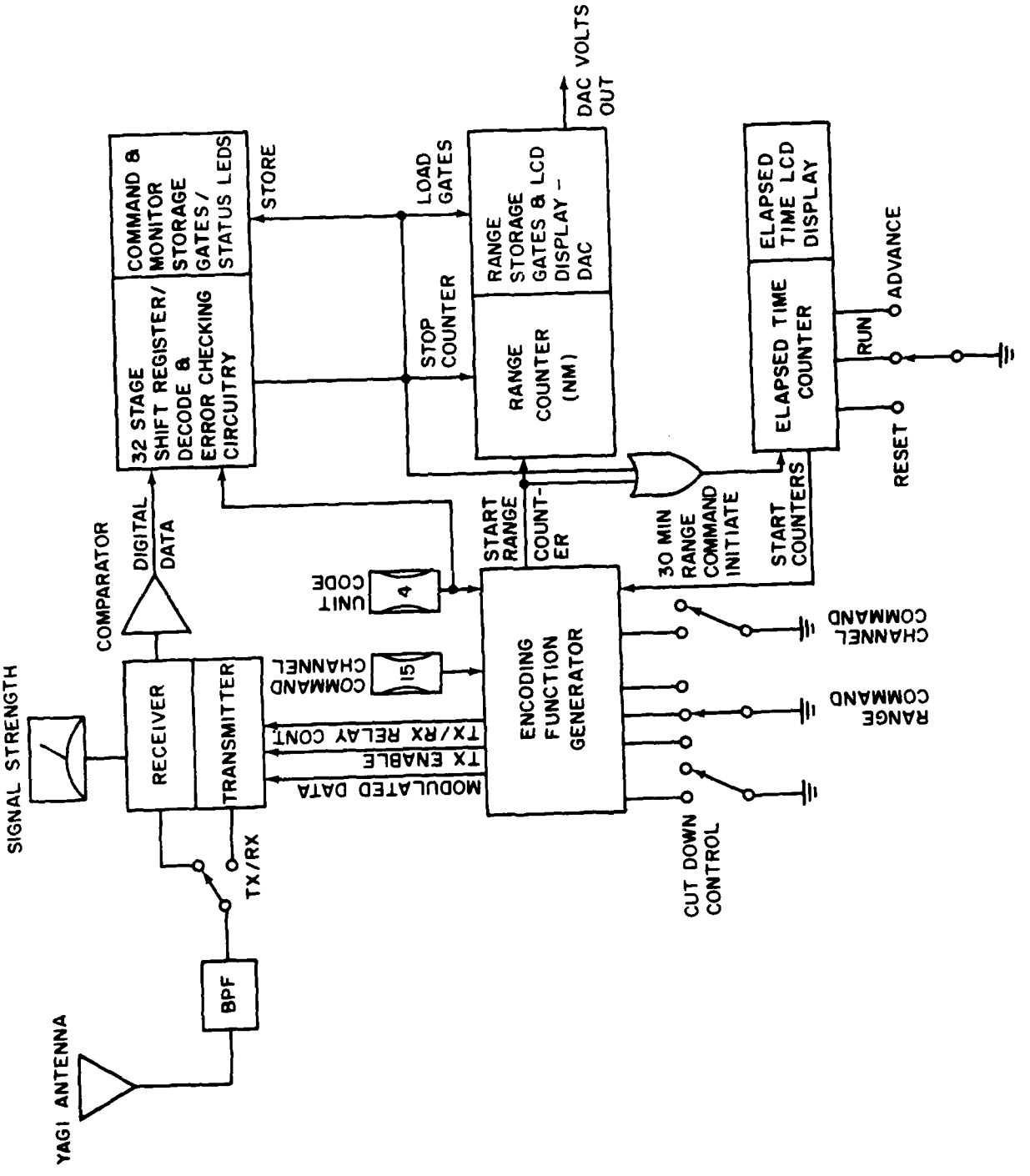

FIG. 5 BASE STATION FUNCTIONAL BLOCK DIAGRAM

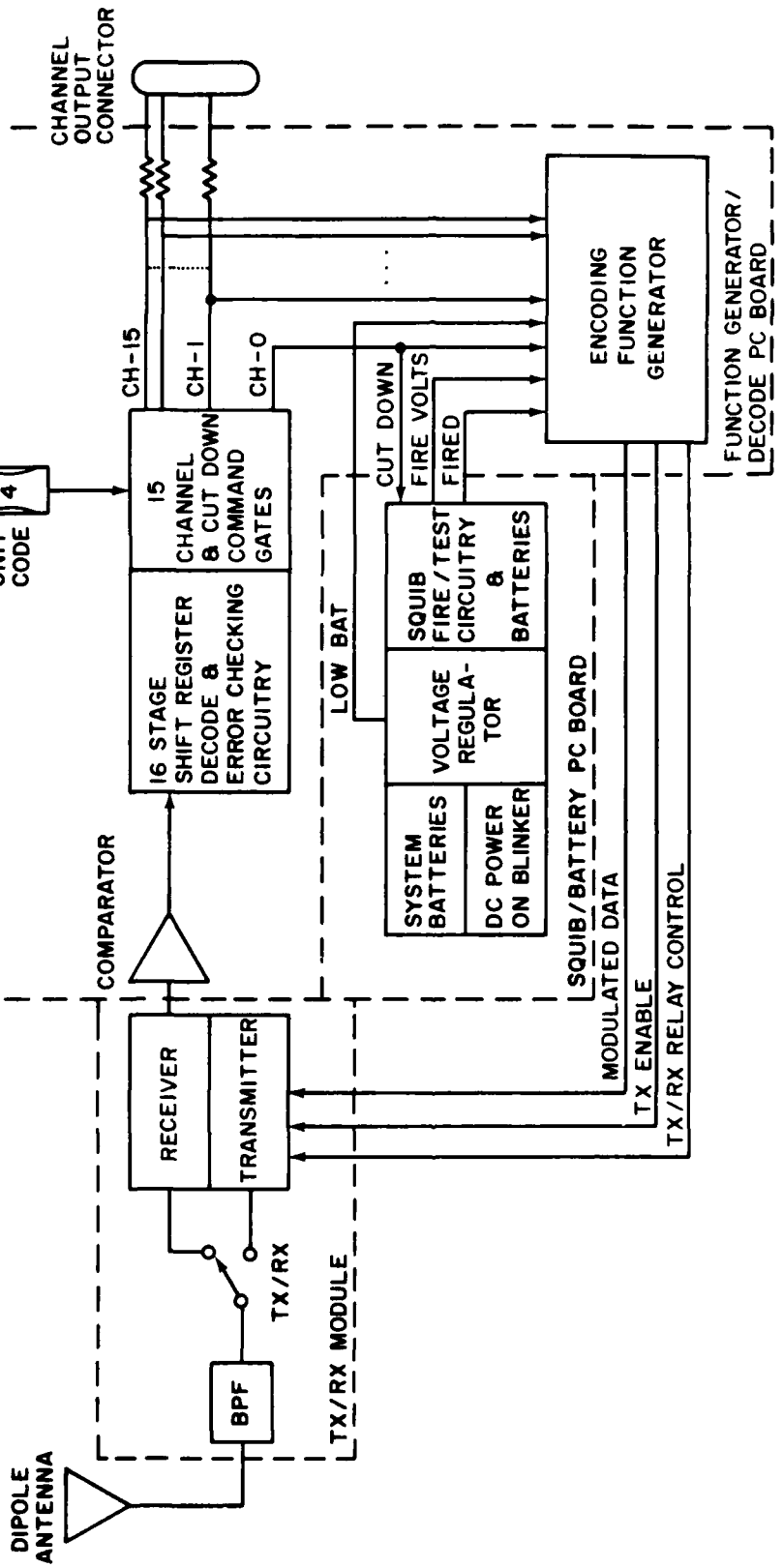

FIG. 6 REMOTE UNIT FUNCTIONAL BLOCK DIAGRAM

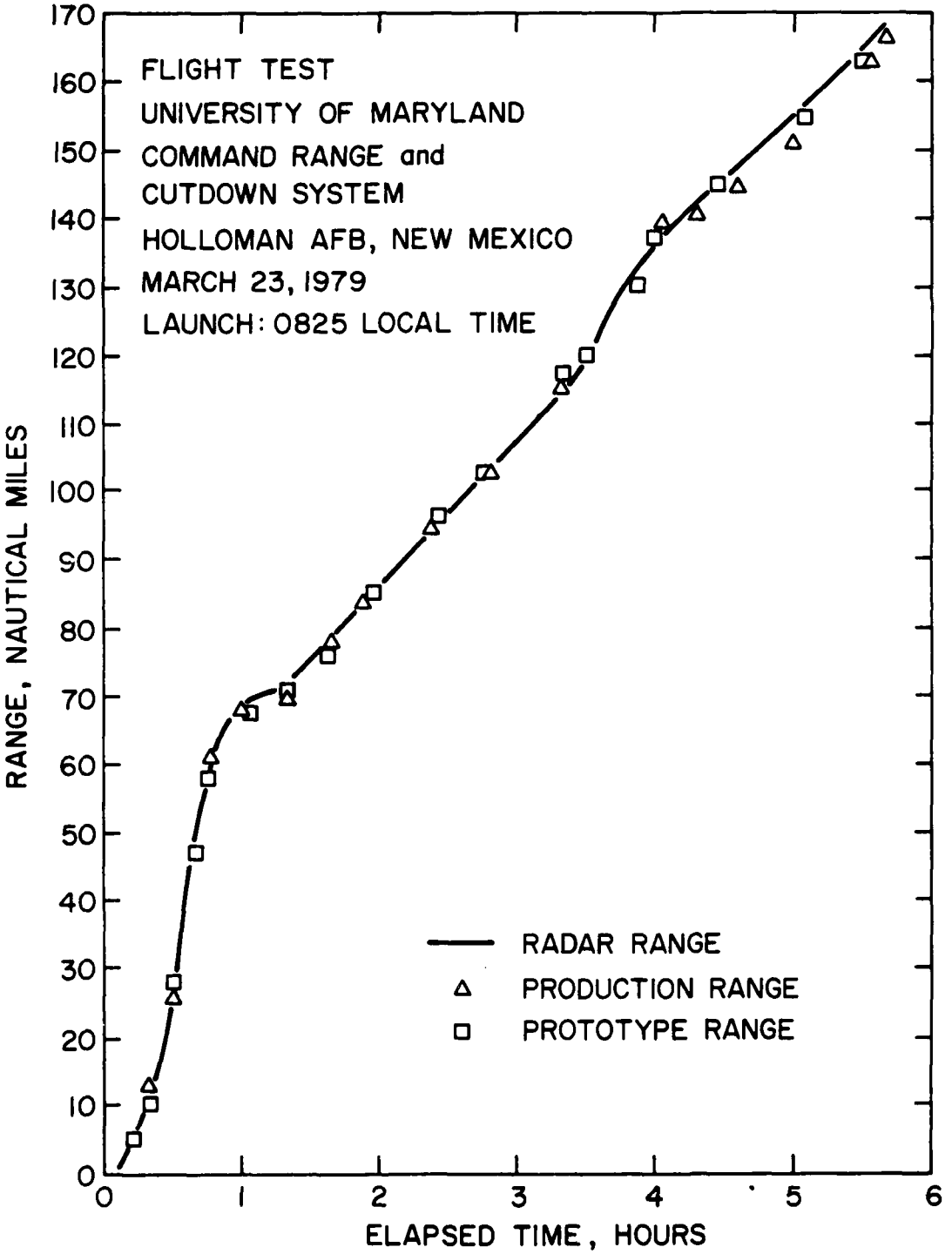

FIG. 7 FLIGHT TEST

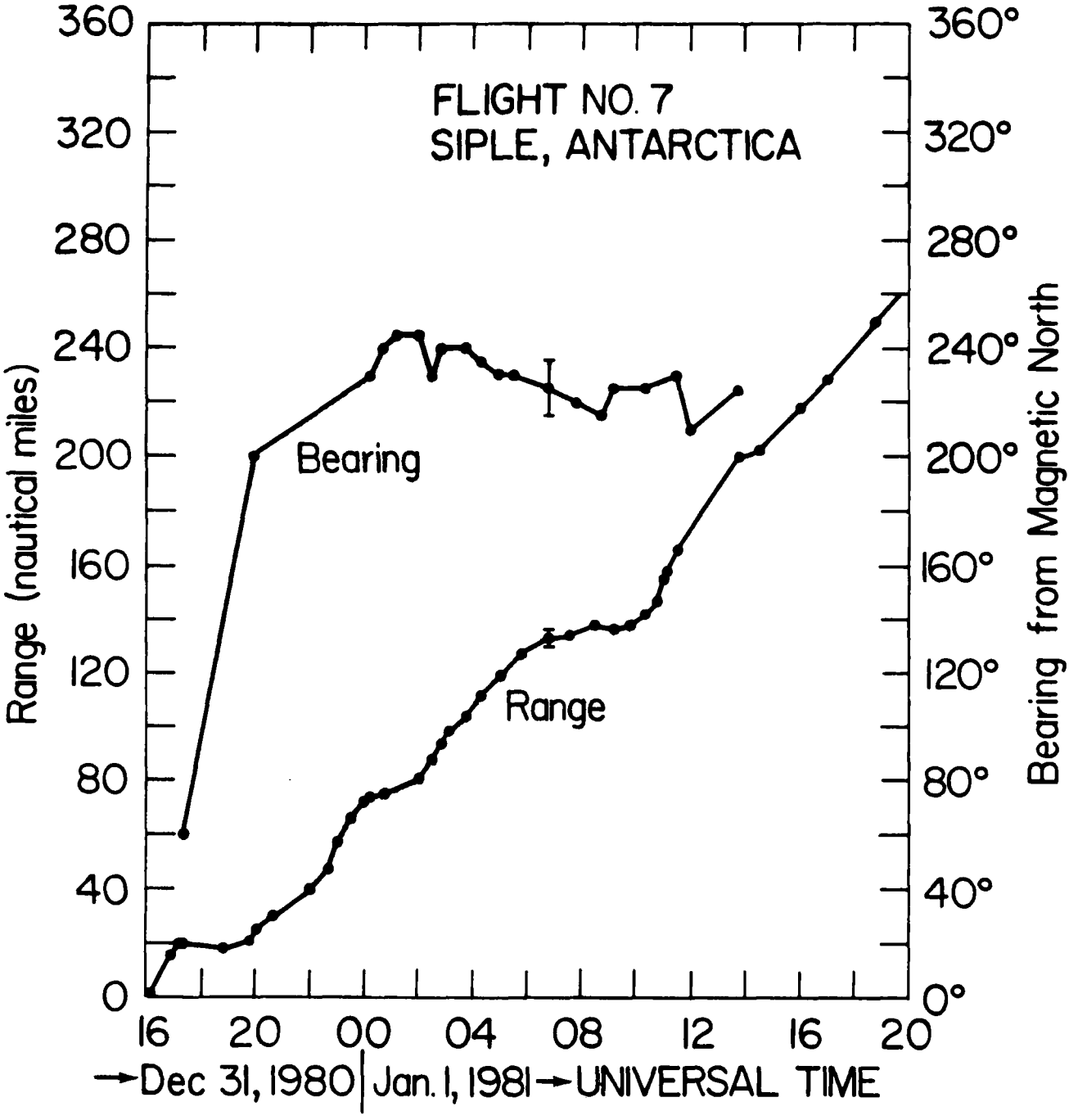

FIG. 8 FLIGHT TEST


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