Automatic Control of DSS 13

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The hardware, software, and control of the automatic pulsar data acquisition system at DSS 13 are described. Details of one observing run using the system are given. Modifications to be made in order to control the system remotely from JPL are described.

I. Introduction

The automatic pulsar data acquisition system at DSS 13 is now operational. The station is controlled completely by the station computers once it is put into a specified initial configuration. Operator intervention can only be accomplished through a computer typewriter. The establishment of automatic control of DSS 13 is one stage in the demonstration of remote automatic control of DSS 13.

In Section II the hardware is described, including the modifications which were made. In Section III the software is described, and in Section IV the operation of the system is summarized. The details of one observing run are given in Section V, and plans for future development are discussed in Section VI.

II. Hardware

Three SDS computers at DSS 13 are involved in the control. The 16-kiloword memory SDS 930 computer is the central computer. It is connected by twin coaxial cable communication links to two 8-kiloword memory SDS 910 computers (Ref. 1). The 910A controls a programmable local oscillator; the 910B controls the antenna. Each of the computers has two timing interrupts: a one-pulse per second (pps) interrupt synchronized with UT and a 50-pps interrupt synchronized with the 1 pps. Each communication link has two associated interrupts at each end. A data interrupt occurs when a word has been sent or received; a status interrupt occurs when the incoming carrier signal is turned off (the normal end-of-message indication) or if an error has occurred. A status register can be read to determine the cause of the status interrupt. The four antenna pointing system (APS) panel interrupts in the 910B corresponding to offset entry and offset clear for each axis are used; the rest are ignored. There is an interrupt generated in the 930 when the pulsar data collector has finished an observation. The interrupts are listed in Table 1.

A few modifications to the hardware at the station were required in order to accomplish the automatic control. The 930 computer memory was increased from 8 to 16 kilowords. The antenna system was modified so that the brakes and speed switches could be controlled by the

910B, and various monitors were added. The integrators in the antenna servo system were bypassed. The switch from antenna input to ambient load was made computer controllable. A special pulsar data collector (Ref. 2) and a control card for the pulsar receiver were built. With these exceptions the station configuration is the same as that for the standard pulsar observing.

III. Software

The 930 is programmed in real-time FORTRAN, which is a standard FORTRAN with modifications for real-time operation. It accepts assembly language code interspersed with FORTRAN code. This allows communication with nonstandard external devices and allows time-critical operations to be written in the more efficient assembly language with access to variables defined in FORTRAN.

The 930 program is an interrupt-driven real-time program. That is, most actions are done in response to interrupts rather than in a specific sequential manner. The background level (the portion of the program executed when no interrupts are active) takes care of operator communication, data processing, and overall program control. In response to the 1-pps interrupt, the instructed antenna position is calculated, and parameters are established for use in the 50-pps routine. Data collection is initiated if requested. A new frequency is sent to the 910A, and the returned frequency is checked when appropriate.

In the 50-pps routine, the information received from the 910B is used to generate antenna commands, and transmission of these commands to the 910B is initiated.

There are two routines for each of the link interrupts, depending on whether the 930 is sending to or receiving from the 910 involved. The 930 is kept in the receiving mode, except when it is actually transmitting a message. Because the data interrupt occurs at a high rate (12 words are sent in each direction between the 930 and the 910B during 20 ms) and the overhead in letting FORTRAN handle the interrupts is high (about 1/2 ms per interrupt), the routines for the data interrupts are written in assembly language.

Because operator communication and data recording both use the same input/output (I/O) channel, they are not allowed to interrupt each other. Both are therefore done on the background level. The only action in response to the data collector interrupt is the setting of a flag.

The 910 programs are written in META-SYMBOL, their assembly language. The communications links are controlled by the same routines (translated into assembly language) as on the 930. The 910A program is controlled by the 930. When a frequency is received from the 930, it is sent to the programmable local oscillator in the 1-pps interrupt routine. In response to the next 1-pps interrupt, the frequency is read in from the oscillator and sent to the 930. The 930 compares the instructed and read-in values and re-sends the instructed value in case of disagreement.

The 910B does most of its computation in the background and in the 50-pps routine. It receives commands and display information from the 930 and sends status information to the 930 fifty times a second. The command in each axis is compared with the previous command and is modified if the acceleration or deceleration is too great. In order to read the positions and send the commands to the antenna at approximately uniform intervals, these are done in the 50-pps routine. The displays and the noncritical status information are taken care of in the background.

IV. System Control

The system is controlled by means of Tutorial Input, a standardized human computer interface developed by A. I. Zygielbaum (Ref. 3) and modified by K. I. Moyd (Ref. 4). The list of Tutorial Input commands is given in the Appendix.

The commands fall into three groups: basic parameter entry, antenna, and data collector. The commands in the basic parameter entry group are used to change the values of antenna parameters and data collector parameters which have been set to default values. Under normal operating conditions the default values are used.

There are two basic antenna modes. In the observing mode the specified coordinates are right ascension (RA) and declination (DEC). The antenna is moved to the assigned source position (subject to wrap-up limitations) and then tracked at the sidereal rate. Observing is initiated when antenna position and velocity errors are less than the tolerances given by the corresponding basic parameters. Tracking continues until the antenna is stopped or until a new antenna command is given.

In the nontracking mode the specified coordinates are azimuth (AZ) and elevation (EL). The antenna is moved to these coordinates and held there (without setting the brakes). No observations are taken. The STOW command has the same effect as an AZEL command with AZ = 180 degrees and EL = 85 degrees in the center wrap-up region.

The antenna can be stopped in two ways. In case a panic stop is needed, a sense switch on the 930 computer is checked once each second. The antenna cannot be moved by the computer as long as the switch is set. A STOP command stops the antenna until a new antenna command is given. In both cases the antenna is safely decelerated in both axes, the brakes are set, and the speed switch is set to low speed.

The data collector takes data in phase with the pulsar period. This is done by setting a reference oscillator to a frequency related to the pulsar period. The data collector uses this reference frequency to generate internal clocks which determine when to sample the input signal and when to reset to the beginning of the period. There are three different ways to initiate a new observation. The observation can be started at the next 1 pps with the data collector memory being cleared first (start-next-second); the observation can be started in phase with the previous observation with the new data being added to the previous data (start-in-phase-add) or with the memory being cleared first (start-in-phase-clear). The first observation on a source is initiated automatically when the antenna is on target with a start-next-second instruction. If no commands are given, subsequent observations are initiated by start-in-phase-add instructions. When a new frequency is set by a PLO command, when an observation is aborted by an ENDO command, or when a TSYN command is given, the next observation is initiated by a start-next-second instruction.

The data collector can be configured to expand the resolution of the data by collecting all the data points during only a fraction of the pulsar period while staying in phase with the preceding observation. The fraction of the period to be observed and the expansion factor are set by an EXP command. The first observation is initiated by a start-in-phase-clear instruction; following observations are initiated by start-in-phase-add instructions. The expansion parameters are used until another data collector command (except WAIT and CONT) is given.

V. Observing Run

On March 20, 1975 the automatic control system at DSS 13 was used for observing pulsars. The station was put into a specified configuration before the observing run was started. Once the computers were given control, all operator interaction was by Tutorial Input through the 930 typewriter with the exception of some offset tests, for which the offsets were entered through the 910B APS panel. Seven different pulsars were observed over a period of eleven hours. Each observation was recorded on magnetic tape and plotted. The magnetic tape has been processed in the same manner as the regularly collected pulsar data. The observations are tabulated in Table 2.

At the end of the observing run, the antenna was moved by the computers to the position to be used for the sky survey and the brakes were set.

VI. Future Development

The object of this project is the demonstration of remote automatic control of DSS 13. The establishment of local automatic control is one stage in the demonstration of remote automatic control. No additional hardware modifications will be necessary in order to include the remote control. There is already a teletype line between the 930 at DSS 13 and an SDS 920 at JPL and a twin coaxial cable link between the 920 and a Sigma 5 at JPL. The software in the 910's at DSS 13 will not have to be changed. The 930 program will be changed so that the Tutorial Input will be done through the Sigma 5 terminal rather than through the 930 typewriter. The Tutorial Input exchanges will be typed out at DSS 13 so that the station personnel will be aware of what is being commanded. A condensed form of the data will be sent to JPL as will various status and error messages. The primary data record will still be the magnetic tape recorded at DSS 13.

References

1. Lushbaugh, W. A., "A Driver/Receiver Unit for an Intercomputer Communications Link," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XV, pp. 109–115, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1973.

2. Brokl, S. S., "Automated Pulsar Data Collector," in *The Deep Space Network Progress Report 42-25*, pp. 129–136, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1975.

3. Zygielbaum, A. I., "'Tutorial Input'—Standardizing the Computer/Human Interface," in *The Deep Space Network Progress Report 42-23*, pp. 78–86, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1974.

4. Moyd, K., "FORTRAN Implementation of Tutorial Input," in *The Deep Space Network Progress Report 42-24*, pp. 88–99, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1974.

Appendix
GTS Tutorial Input Commands for DSS 13 Automation

I. Basic Parameter Entry

Command	*Parameter*	*Description*
OFFD		Change default offsets. New values will be used immediately.
	AZDF	Default azimuth offset in degrees. Initially: .145.
	ELDF	Default elevation offset in degrees. Initially: 0.
DIST		Change pointing parameters. The new values will not be used until a new antenna command is given. Values are to be entered in millidegrees (i.e., 10 degrees is entered as 10000).
	HSPD	Minimum azimuth pointing error for which high speed is to be used. Elevation value is half of azimuth value. Initially: 12000.
	DECL	Azimuth pointing error at which high-speed deceleration is started. Elevation value is half of azimuth value. Initially: 10000. (It is required that DECL < HSPD.)
	TRKD	Maximum pointing error (in each axis separately) for on-target condition to be satisfied. Initially: 50.
	TRKV	Maximum velocity error (in each axis separately) for on-target condition to be satisfied. Initially: 25.
PDCL		Change default pulsar data collector parameters. The new values will be used the next time parameters are sent to the data collector (i.e., following an OBJ, GO, TSYN, ENDO or EXP command).
	XDEF	Number of synthesiser pulses between observations. Initially: 200.
	YDEF	Number of observations per period. Initially: 5000.
DATE		Enter date. (Date is based on UT, not on local time.)
	MON	Month — up to 4 numbers or letters.
	DAY	Day of the month.
	YEAR	Year — 4 digits.

II. Antenna Commands

A. New Position

These are acted upon immediately if the previous antenna command was STOP, AZEL, or STOW; if the antenna was stopped by the computer for another reason (breakpoint 4 set and then reset, elevation too low); or when the program is first started. Otherwise they will be acted on after the current observation is finished and the data processed.

Command	*Parameter*	*Description*
AZEL		Move the antenna to the specified azimuth and elevation and hold it there. Do not collect data.
	AZ	Azimuth between 0 and 360 degrees with up to three decimal places. The decimal point must be typed.
	EL	Elevation in degrees with up to three decimal places. The decimal point must be typed.
	REGN	Wrap-up region. 'R' for right, 'L' for left. Anything else will be interpreted as center.
STOW		Move the antenna to the stow position (AZ = 180 degrees, EL = 85 degrees, center region) and hold it there.
OBJ		Move the antenna to the specified right ascension (RA) and declination (DEC) and track. When the antenna is on-target, initiate data collection with a start-next-second.
	ID	Pulsar identification number — up to 4 digits.
	RA	Hours of RA.
	RAM	Minutes of RA.
	RAS	Tenths of seconds of RA (i.e., 34.5 seconds is put in as 345).
	DEC	Degrees of DEC. Include sign if negative.
	DECM	Minutes of DEC, no sign.
	DECS	Seconds of DEC (2 digits), no sign.
	TMCN	Time constant setting for the pulsar receiver.

B. Other Control Commands

STOP	Stop the antenna (decelerate safely, put on the brakes, change to low speed). Ignore any data being taken. Acted upon immediately. To resume operation, one of the other antenna commands must be given.
GO	Resume observation of the object entered by the previous OBJ command. Used after the antenna has been stopped. Acted upon immediately unless breakpoint 4 is set.

III. Data Collection Commands

All of the commands except ENDO are acted upon only after the data from the current observation has been processed.

Command	*Parameter*	*Description*
LINK		Enable the 930 — 910A link.
NLNK		Disable the 930 — 910A link. (This is the initial condition.)
PLO		Entry of oscillator frequency. If the 930 — 910A link is enabled, the frequency will be sent to the local oscillator and the setting will be confirmed. The next observation will be a start-next-second.
	FREQ	Oscillator frequency in hertz. Up to 10 characters including the decimal point.
WAIT		Do not start the next observation until another command has been received. This allows the operator to see the data before specifying a new observation.
CONT		Initiate a start-in-phase-add after a WAIT command has been given.
TSYN		Initiate a start-next-second. (This is done automatically for the first observation after an OBJ, GO, PLO or ENDO command.)
ENDO		Abort the current observation and ignore the data. It is acted upon immediately if an observation is in progress. Otherwise it has no effect. If no other command is received, the next observation will be a start-next-second.
EXP		Subsequent observations are to be expanded. The parameters are based on the data taken as the result of the previous start-next-second command. These expansion parameters will be used until an antenna command, PLO, TSYN, ENDO or another EXP command is given.
	DEL	The original data point (between 0 and YDEF-1) corresponding to the 0th observation (i.e., origin) for the expanded observations. If DEL = 0, the origin is in phase with the second at which the original observation was taken.
	IINT	The number of *original* data points to be included in the expanded observations.
	IEXP	The expansion factor (number of observation points for each original observation). IEXP must be a factor of XDEF. IEXP $\times$ IINT $\leq$ 5000.

Table 1. Interrupts

	Level[a]	Interrupt
910 A		
	201	1 pps
	220	Link to 930 — data interrupt
	221	Link to 930 — status interrupt
910 B		
	200	50 pps
	205	Enter azimuth offset
	206	Enter elevation offset
	214	Clear azimuth offset
	215	Clear elevation offset
930		
	200	Link to 910 B — data interrupt
	201	Link to 910 B — status interrupt
	202	Link to 910 A — data interrupt
	203	Link to 910 A — status interrupt
	204	50 pps
	205	1 pps
	207	Data collector

[a]The lower the level, the higher the priority.

Table 2. Pulsar observations on March 20, 1975

ID number	Start time, UT	Number of observations
1929	17 51 24	27
0329	20 40 28	14
0628	22 20 59	7
0355	23 46 11	14
0823	01 01 03	16
0736	02 28 34	6
0833	03 21 45	8
0329	04 01 47	4
0833	04 38 25	4