A Computer Routine for Relay I Trapped Proton Distributions

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1. Introduction

This note is to describe the Fortran routine RELAY I for scientists who desire easy computerized access to the trapped proton distributions measured by satellite Relay I. It has been pointed out by McIlwain [1963] that the vast quantities of data gathered by satellites are often difficult or inconvenient to use in conventional printed form, and that a suitable computer program is an appropriate means to communicate these data. A program has been written to transmit Relay I results in a fashion similar to McIlwain's program for Explorer XV, although the computation procedure is not the same. This program has been run in both Fortran IV and Fortran 63, with differences in control cards and in the names of library functions being the only concerns of the general user. It has been deposited in the National Space Science Data Center, and duplicate decks may be obtained by writing

National Space Science Data Center
Goddard Space Flight Center
Greenbelt, Maryland 20771

2. Instrumentation

The instrumentation of Relay I has been described in other reports [Fillius, 1963; Fillius and McIlwain, 1963; McIlwain et al., 1964]. Table I is a summary of the orbit and detectors for convenient reference.

Table I

Relay I Orbit and Instrumentation

Relay I Satellite

Launch:	12/14/62
Inclination:	47.5^{o}
Perigee:	1300 km
Apogee:	7500 km
Anomalistic Period:	185 min.
Spin Rate:	2.7 rps

Detector A

Sensor:	0.9 cm sphere of plastic scintillator
Geometric Factor:	0.33 cm^2 omnidirectional
Shielding:	1.3 gm cm^{2} Al over one hemisphere
Proton Range:	> 33.5 MeV

Detector B

Sensor:	Silicon surface barrier diode with depletion depth 25 mg cm^{-2}
Geometric Factor:	0.0136 cm^2 ster directional *
Shielding:	1.115 mg cm^{-2} (air equivalent) Ni light shield over look cone
Proton Ranges:	1.1 to 14 MeV 1.6 to 7.1 MeV 2.25 to 4.7 MeV

Table I (cont.)

Detector C

Sensors:	Two silicon Li drift diodes with active depths of 107 and 132 mg cm^{-2}, operated in coincidence
Geometric Factor:	0.22 cm^2 ster directional *
Proton Ranges:	18.2 to 25 MeV
	25 to 35 MeV
	35 to 63 MeV

Detector D

Sensor:	0.25 cm cylinder of plastic scintillator
Geometric Factor:	0.0027 cm^2 ster directional *
Proton Range:	> 5.2 MeV

* The directional detectors are mounted perpendicular to the satellite spin axis and are gated by a magnetometer to record data only when they point within $\pm 10^\circ$ of the plane perpendicular to the local magnetic field vector. Thus they measure $j_\perp$, the flux of locally mirroring particles.

3. Data Reduction Procedure

Data reduction was carried out by a procedure originally used by McIlwain for Explorer XV. The counting rates from each detector were interpolated in time to every crossing of selected magnetic shells (L = 1.5, 1.6, 1.7, etc.). A least squares fit was then made to the data for each L shell using the function

$$\ln_e \; (CR) = A_1 + A_2 t + A_3 (B/B_o) + A_4 (B/B_o)^2 + \ldots + A_n (B/B_o)^{n-2} \qquad (1)$$

where

$B_o = \frac{.311653}{L^3}$ is the value of the magnetic field at the equator for that L,

$3 \leq n \leq 8$ is selected by the computer or by the programmer for the best fit.

CR is the counting rate,

t is numbered in days and fractions, beginning with 1 on January 1. 1963. The coefficients A_1 through A_n are punched out on IBM cards which also contain the L value, the range of B covered by the data, and 100 times the rms average of the residuals. In the approximation of a good fit the last number resembles a per cent error; however, it is not to be taken as an error bracket, since counting statistics can range by several orders of magnitude over the entire shell of force. It is an indicator of the quality of the data and fit. The omnidirectional data from detector A is carried through the above procedure and then is converted to directional flux by computation combining the methods of Farley and Sanders [1962] and Roberts [1965]. New cards are then punched for the directional coefficients. The routine RELAY I uses these decks as the input data to determine the flux at an arbitrary point in B, L space.

4. Coverage

The decks provided with RELAY I cover eight energy ranges of trapped protons over most of the orbit from 1.2 to 2.2 earth radii. The routine returns values for the proton flux in a specified range as it stood on the date shown in Table 2.

Table 2

Deck Number	Energy Range	Reference Date
1	1.1 - 14 MeV	1/1/63
2	1.6 - 7.1	1/1/63
3	2.25 - 4.7	1/1/63
4	> 5.2	7/1/63
5	18.2 - 25	1/1/63
6	25 - 35	1/1/63
7	35 - 63	1/1/63
8	> 35	7/1/63

5. Method of Computation

On the first call to RELAY I the data decks are read in and stored in tables. On a call to a general point B_1, L_1, the specified table is searched for four L values bracketing L_1. Interpolation is then made to B_1, L_1 along the three paths of constant B, constant B/B_o, and constant radial distance, using a least squares parabolic fit to $\ln_e$ (CR) evaluated at the four grid points. The flux returned by the program is computed from the average of these three interpolations $\varphi = (1/G) \exp (\sum_{i=1}^{3} (\ln_e \mathrm{CR})_i /3)$ where G is the geometric factor in cm^2 ster. In the event that a suitable grid does not exist, or if the requested point lies outside the B limits of the Relay data, the program returns a negative answer. If one or more of the interpolations cannot be made, the program returns the average of those that can. This fitting and averaging procedure serves to smooth the data.

Also returned is an indicator of data reliability. This indicator is computed starting with the average over the four grid lines of the rms average of the residuals to the fit. An rms average is taken between this and the variance of the three interpolations, and the result is expressed as a per cent of the computed flux. This number is flagged to 100 per cent when the points are interpolated near or extrapolated beyond the boundaries of the coverage. Once again, this is not the probable error, but only an indicator of quality.

6. Call Parameters

The subroutine has a five-parameter call list: CALL RELAY I (NA, B, EL, AJ, R).

NA — is a fixed point number specifying the proton energy range desired (see Table II)

B — is a floating point number specifying the magnetic field at which the intensity is desired. B can be given in gauss ($B < 1$) or it can be normalized to the equator for the specified shell of force ($B \geq 1.$). The routine will recognize which way B has been specified.

EL — is a floating point number which specifies the L value at which the intensity is desired.

AJ — is a floating point number specifying the returned intensity in units of protons cm^{-2} sec^{-1} $ster^{-1}$. If measurements were not obtained at the point specified, AJ will be given as -.1.

R — is a floating point number giving an indication of data quality. Its computation is explained in section 5.

7. Subroutines

RELAY I uses the following special subroutines: INTERP, DEPUNC, JSERIE, RLAMDA, and PARFIT. Their functions are listed briefly below:

RELAY I — is the head subroutine. It initializes the data arrays and feeds INTERP.

INTERP — directs the computing. It calls subroutines JSERIE, PARFIT, and RLAMDA for subcomputations and produces the average interpolations.

JSERIE	evaluates the fitting function on the L shell for a given B.
RLAMDA	obtains R given B and L.
PARFIT	computes the least square parabolic fit to the values on the four L lines surrounding the requested point.
DEPUNC	decodes the data cards for RELAY I.

8. Timing

RELAY I averages about 25 milliseconds per call on CDC 3600.

9. Diagnostic Printing

The interval variable KEYPNT in RELAY I controls a printout option. If no internal printout is observed, leave KEYPNT = 1. If the results alone are desired, set KEYPNT = 2. A line will be printed in the format:

DECK B L TIME FLUX QUALITY

If KEYPNT = 3, an extensive printout is called, including the table of coefficients on the first call. This option is intended only for trouble-shooting.

10. Tape Assignments

The data cards are read in from LOGICAL UNIT 5.

Under KEYPNT options 2 and 3, the output is printed on LOGICAL UNIT 6.

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