USER GUIDE FOR ISEE-3 RADIO MAPPING EXPERIMENT CD-ROM DATA

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(Excerpted and revised from a document by S.E. Kayser)

1. GENERAL DESCRIPTION OF THE ISEE-3 RADIO MAPPING EXPERIMENT

The ISEE-3 Radio Mapping Experiment is designed to detect and measure radio bursts from the Sun, the interplanetary medium, and the Earth's magnetosphere, at frequencies from 30 kHz to 2 MHz. It is a collaboration of the Observatory of Paris-Meudon and the Goddard Space Flight Center; the Principal Investigator is Jean-Louis Steinberg. The experiment determines the direction of sources and estimates their apparent angular sizes using two dipole antennas. One dipole, the shorter of the two, is along the spin axis of the satellite, while the second dipole is perpendicular to the spin axis and is therefore carried around by the rotation of the satellite. Each of the monopoles making up the spin-axis dipole can be extended to 7m, whereas each monopole making up the dipole in the spin plane is 45m long. The signal received by the spinning dipole is modulated, being strongest when the dipole is perpendicular to the direction of the source. The phase of the spin modulation provides information on the direction of the source, projected onto the plane in which the dipole is spinning, and the amplitude of the modulation determines the angular size of the source as a function of its elevation above or below the spin plane. The additional information provided by the spin-axis dipole helps determine whether the source is above or below the spin plane, and its elevation.

The incoming signal is processed by electronics which select a frequency channel and bandwidth, filter the signal, amplify it, etc. The output is an analog voltage corresponding to the logarithm of the square of the amplitude of the incident electromagnetic field. Finally, the data processing unit (DPU) digitizes the data and prepares it for transmission.

Upon receipt at Goddard Spaceflight Center, the data from the ISEE-3 Radio Mapping Experiment were routinely processed. Several datasets produced by this processing have been archived with the National Space Science Data Center (NSSDC) as described below.

2. DETAILED DESCRIPTION OF THE DATA AND DATA PROCESSING

2.1 Detailed Description of the Data Acquisition

The experiment is designed to make a series of measurements at each frequency (listed in Table 2-1), covering one-half spin. Such a series is called a step. The specifics of the data are described below. In this document, the spin-axis dipole is called the Z-dipole, because the spin axis is labeled the z-axis of the satellite-based coordinate system. The other dipole is called the S-dipole, because it is spinning. ISEE-3 has two spinning dipoles, called U and V. Only the V dipole was used to acquire radio data.

Table 2-1. ISEE-3 Frequencies

Channel No.	Receiver Freq. (Khz) Broad	Narrow
1	1980	1000
2	1000	466
3	513	290
4	360	188
5	233	145
6	160	110
7	123	80
8	94	66
9	72	56
10	60	47
11	50	36
12	41	30

2.1.1 Mode and bit rate - Measurements are made at twelve frequency channels with a 10 kHz (broad) bandwidth and twelve interleaved frequencies with a 3 kHz (narrow) bandwidth (see Table 2-1). The principal mode of operation alternates a broad band measurement with a narrow band measurement of the same frequency channel number. This is called Mode 1. Only broad band (B) measurements are made in Mode 2, and only narrow band (N; sometimes called b) in Mode 3.

Data were usually transmitted at 2048 bps at the beginning of the mission. There was a planned provision made for transmission at 1024 or 512 bps. In this document, Modes 1, 2, 3 at 1024 bps are called Modes 4, 5, 6. At 512 bps they are called Modes 7, 8, 9. Mode and bit rate are coded together in this way in all data sets. Later in the mission, data was acquired at 256, 128, and 64 bps; the mode-naming convention was extended from 10-18 to account for these unexpected data rates. In the remainder of the document, we refer to Modes 1, 2, and 3, to mean the modulus of the mode with 3, i.e., statements that apply to Mode 3 also apply to Mode 6.

2.1.2 The Frequency Sequence - The twelve frequency channels are sampled in a fixed 72-step sequence lasting 108 seconds, such that the higher frequencies (lower channel numbers) are sampled more often than the lower frequencies. The 72-step sequence is presented in Table 2-2. For any given frequency, the time interval between successive samples is constant. Since type III solar bursts have a shorter duration at the higher frequencies, this sampling sequence provides approximately the same number of measurements per burst at all frequencies.

Table 2-2. The 72 Step Frequency Sequence

Steps	Frequency Channels											
1-12	1	2	5	1	3	8	1	2	6	1	4	11
13-24	1	2	7	1	3	9	1	2	5	1	4	10
25-36	1	2	6	1	3	8	1	2	7	1	4	12
37-48	1	2	5	1	3	9	1	2	6	1	4	11
49-60	1	2	7	1	3	8	1	2	5	1	4	10
61-72	1	2	6	1	3	9	1	2	7	1	4	12

2.1.3 The S and Z Samples - Each frequency channel, or pair of channels in Mode 1, is sampled for 1. 5 seconds, which is approximately half the spin period. At the top data rate, 2048 bps, 24 samples are made in this interval. In Mode 1, there are 22 samples from the spinning S-dipole in alternating bandwidths, followed by a measurement from the Z-dipole in each bandwidth. The set of 11 S-samples in each bandwidth cover nearly half a spin, so that almost the full range of signal modification due to the spin is experienced. In Modes 2 and 3, there are 23 S-samples, followed by a Z-sample. At lower data rates, each channel is still sampled for 1. 5 seconds, but fewer measurements are made at each frequency. Thus, at 1024 bps, only 12 samples are made, consisting of 5 S-samples in each bandwidth followed by 2 Z-samples, or of 11 S-samples all in one bandwidth followed by a Z-sample.

Each sample is integrated through a second-order filter with an effective time constant of 44.2 msec for the S samples and 260 msec for the Z samples. The output of the logarithmic square-law detector is between 0. and 5. volts, which is digitized into 256 steps, at 0. 02 v/step.

2.1.4 Phase - In addition to the S and Z samples, in each step two measurements are made of the normalized phase difference between the S and Z samples. This is done by adding the normalized S and Z dipole outputs before entrance to the square-law detector.
It is then integrated by an RC filter with a time constant of 39 msec. As described in the document "Determination of Radio Source Parameters Using Two Crossed Dipoles" (S.E. Kayser, 1979), the phase is useful in determining the elevation of the source.

In Mode 1, at any bit rate, the first phase sample is broadband, and the second is narrowband. In Mode 2 both are B, and in Mode 3 both are N.

2.1.5 Internal Calibration - A calibration mode is available in which an internal noise signal with six levels of attenuation is applied to the radiometers. Instead of the usual 72-step frequency sequence, each of the twelve channels or pairs of channels is sampled in turn, with one cycle of channels for each increasing level of noise. Two consecutive 72-step sequences are made, for the - and the + antennas, respectively. In Mode 1, the first of these uses B status coding and the second *is* N. The S and Z samples for each step are taken in the same order as for the data Modes 1-9.

This mode is entered automatically about every 18 hours or on command. A calibration sequence always begins at the start of major frame type. The previous sequence is left unfinished. After the two calibration sequences are complete, a new data mode 72-step sequence begins, with B status coding for Modes 1 and 2.

The calibration steps are identifiable only because their frequency sequence is 1, 2, 3, 4, . . . 11, 12, 1, 2.... instead of 1, 2, 5, 1, ... There is no indication in the digital subcom.

2.2 Demodulating the data

2.2.1 Basics - The direction to the source and the source strength are determined from the spin-modulated S samples and the Z sample by the procedure described in the following section. The linear least-squares solution provides a despun source amplitude A, which is its maximum amplitude, observed when the S dipole is "broadside" to the source, the azimuth angle with respect to the Sun of the source center in the spin plane, and a measure of the modulation of the source due to the changing orientation of the S dipole, called alpha. The standard deviation of the least-squares fit and the uncertainties in the three parameters are also calculated. Comparison of the Z sample and A with the modulation index alpha permits to evaluate the source radius and its elevation from the spin plane.

2.2.2 Method - A full discussion of the principles and algorithms employed to obtain the source direction, size, and strength is available in the document "Determination of Radio Source Parameters Using Two Crossed Dipoles (One Spinning)," CSC/TM-79/6265 (S.E. Kayser, 1979).

Three parameters - the mean amplitude A, the modulation index alpha, and the source azimuth phi are obtained by a least-squares fit of one group of S samples (a group consists of the S samples of the same frequency in one 1.5 sec record) to the equation

$$R = A\ (1 + \text{alpha} \cos 2\ (wt - \text{phi})\ )$$

where w is the spacecraft spin rate and R is the antenna temperature at time t (for an S sample). The angle wt is the Sun angle. By rewriting the equation as

$$R=A1 + A2 \cos 2wt + A3 \sin 2wt$$

where A1 = A, A2 = A alpha cos(phi), and A3 = A alpha sin(phi), a linear least-squares solution in closed form is achieved.

The elevation of the source from the spin plane and the effective radius (assuming a uniform circular source) act jointly on all of the three parameters sensitive to them. The three parameters are the modulation index alpha, the ratio of antenna temperatures Z/A, and the phase measurement. Unfortunately, Z and A are not measured with sufficient sensitivity to give a reliable determination of the radius and source elevation. More accurate values have been obtained by using all of the phases collected for a given event (and assuming that the source did not vary in elevation over time). These results are not available on the ISEE-3 CD-ROM. See Section 4 for additional information.

Determination of the source azimuth can be made only within a 180 deg ambiguity, as can be seen in the above equation containing 2wt. By identifying the nature of the source, e. g. Earth noise or a solar burst, it is usually clear which azimuth is correct.

It should be noted that the azimuth is considered to be positive when west of the Sun. Since ISEE-3 rotates counter-clockwise, the Sun angle wt increases in the opposite direction to azimuth.

3. CONTENTS OF THE ISEE-3 RADIO DATA CD-ROM

3.1 Preparation of the ISEE-3 Radio Data CD-ROM

These data exist in VAX floating point format, because VAX computers were the systems used by both of the collaborating groups in the latter phases of the ISEE-3 mission. Section 3.2 lists the directory structure of one of the CD-ROMs. In addition to the data files, there are software stubs for reading the data on VAX and Sun Unix systems, including a routine for converting from VAX floating point to IEEE format.

3.2 Organization of the CD-ROM

Following is a directory structure for the ICE_RADIO_DATA

CDROM:

```
cdrom --|---    aaareadm.txt
        |
        |---    documents ----------       requirements.txt
        |                                  gzip.doc
        |                                  ice_108.txt
        |                                  ice_15s.txt
        |                                  ice_demod.txt
        |
        |
        |---    data      ----------|----  1_5s   ----- imyymmdd.gz
        |                           |
        |                           |----  108    ----- iayymmdd.gz
        |                           |
        |                           |----  demod  ----- idyymmdd.gz
        |                           |
        |                           |----  edr    ----- *.edr
        |                           |
        |                           |----  plots  ----- yymmdd.ps
        |                           |
        |                           |----  missing.txt
        |
        |
        |--- software --|--- sun ---|----  bin    ----- vax_to_sun
        |               |           |
        |               |           |
        |               |           |----  source ----- *.F
        |               |
        |               |
        |               |
        |               |--- vax ---|----  exe    ----- *.exe
        |                           |
        |                           |
        |                           |----  source ----- *.for
        |                                               *.c
        |
        |
        |---    zip       ----------|----  source ----- GZIP source
                                    |                 & build files
                                    |
                                    |----  sun41x ----- gzip
                                    |                   gunzip
                                    |
                                    |----  vms    ----- gzip.exe
```

gunzip.exe

3.3 Data file contents

There are 3 different sets of data files on the CD-ROM that are of potential interest to new users - 1.5 sec modulated data, 108 second averages, and 1.5 sec demodulated data. The 1.5 sec modulated data files contain individual data samples, calibrated in units of antenna temperature. The spin modulation has not been removed from these files. The 108 sec average files are simple averages of the 1.5 sec modulated data as a function of frequency. (Note that the average is done in log space, I.e., mean(log(antenna temperature)).) Finally, the 1.5 sec demodulated data file contains the parameters A, alpha, and azimuth. The demodulated data file is the file that most users will want to use.

Table 3-1. Contents of the ISEE-3 Radio 1.5 sec Record

VARIABLE	DIM	#	DESCRIPTION
IYDD			Julian date of data as YYMMDD
IHMS			Time of first S sample, as HHMMSS
MSEC			IHMS in millisecs of day
NFREQ			Frequency channel 1-12
SAMP	24		Calibrated S & Z samples as log TA Contents depend on mode & bitrate
SM	4	1	SB average for modes 1&2,SN average for mode 3.
		2	SN average for mode 1; 0 else
		3	SN rms for modes 1 & 2, SN rms for mode 3
		4	SN rms for mode 1; 0 else
GSE	3	1	X geosolar ecliptic coord in meters
		2	Y
		3	Z
SPIN			Spin period in msec
SUNANG			Dipole azimuth at msec, angle between sun and S-dipole normal in radians.
NHOUSE	10	1	Byte 1 Step number 1-72 Step +100 for cal or unknown Byte 2 Status

	Byte 3 first phase
	Byte 4 second phase
2	Byte 1 # non-fill S samples
	Byte 2 record quality
	Byte 3 mode
	Byte 4 spare
3	Status words by byte
4	Status words by byte
5	Julian date of processing
6	Frame rate in microseconds
7-10	Spares

Note: The first 4 1*4 elements of the NHOUSE array are written out as single bytes on the CD.

All variables are standard FORTRAN type.

Table 3-2. Contents of the ISEE-3 Radio 108 sec Average Record

VARIABLE	DIM	#	DESCRIPTION
IYDD			Julian date of data as YYDDD
MSEC			Time of record in msec
SMM	12x4	12x...	S sample of 108s log ave. as log TA. The first index is for the 12 frequency channels.
		x1	The second index: The SB average for modes 1&2 and SN for mode 3
		x2	The SN average for mode 1 else 0
		x3	The SB rms value (SN for mode 3)
		x4	The SN rms value for mode 1
ZMM	12x4	12x4	Z sample 108s averages in log TA. Indices as SMM
NHOUSE	10	1	Mode
		2	X Geocentric solar ecliptic
		3	Y coordinates in meters
		4	Z
		5	Z dipole configuration
		6	Julian date of processing
		7-10	Spare

All variables are standard FORTRAN type.

Table 3-3. Contents of the ISEE-3 Radio 1.5 sec DEMOD Record

VARIABLE	DIM	#	DESCRIPTION
MDATE			Julian date of record (YYDDD)
MHMS			Time of midpoint of record in hhmmss
MSEC			Time of midpoint or record in msecs
NFREQ			Frequency channel 1-12
ADSP	4	1	Despun SB amplitude (or SN for Mode3)
		2	Despun SN amplitude if mode 1
		3	Log of SB as log TA
		4	Log SN if mode 1, else 0
ALPHA	2	1	Modulation Index for B(or N if mode3)
		2	Modulation Index for N if mode 1, else 0
PHI	2		Source longitude(increasing to west of sun) for B, N in degrees (-90 - 90)
Z	4		Average Z amplitude - elements as for ADSP
PHASE	2		Phase(volts) for the first input record used in group for B, N(or both B for mode 2, both N for mode 3)
PHANG	2		Phase sun angle for B,N in radians
ELEV	2		Calculated elevation angle for B,N
RAD	2		Calculated source radius for B,N in degrees
BW	4	1	Background value used for SB in calculating ELEV and RAD
		2	Background value used for SN (mode 1)
		3	Background value used for ZB
		4	Background value for ZN if mode 1
ST	2		Fractional standard deviations of least squares fit for B,N
SIGA	3x2		Uncertainties in parameters for least squares fit
		1x	Uncertainty in mean SB, SN amplitude
		2x	Uncertainty in alpha for B,N
		3x	Uncertainty in PHI for B, N in degrees
NSAMP			Number of S samples in fit
IQUAL	2		Quality of analysis B, N
KDATE			Julian date of processing
MODE			Data mode
SPINP			Spin period in msec
GSE	3		XYZ coordinates Geocentric solar ecliptic in meters
SPARE	10		Spares

All variables are standard FORTRAN type.

3.4 Conversion from antenna temperature to flux density

A conversion of these values in antenna temperature to values in flux density may be desired. The following equation provides that conversion to solar flux units (1 sfu = 1.0 e-22 W/m^2/Hz).

sfu = 2.571 e-11 * freq^2 * antenna_temperature

where freq is in kHz

4. OTHER SOURCES OF INFORMATION

For additional information about the ISEE-3 radio data, contact:

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