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A flexible format for exchanging pulsar data

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Abstract. We describe a data format currently in use amongst European institutions for exchanging and archiving pulsar data. The format is designed to be as flexible as possible with regard to present and future compatibility with different operating systems. One application of the common format is simultaneous multi-frequency observations of single pulses. A data archive containing over 2500 pulse profiles stored in this format is now available via the *Internet*, together with a small suite of computer programs that can read, write and display the data.

Key words: pulsars: general — astronomical databases: miscellaneous

1. Introduction

The **E**uropean **P**ulsar **N**etwork ("**EPN**") is an association of European astrophysical research institutes that co–operate in the subject of pulsar research. All institutes have up until now developed their own individual hardware and software facilities tailored to their own requirements and will, of course, continue to do so in future. Contact and co–operation has always existed between the scientists of the member institutes and outside, but the lack of a common standard format for pulsar data has hampered previous collaborative research efforts.

In this paper, we describe a flexible format that we have developed for exchanging data between EPN pulsar groups. The format has some generic similarities to the widely used FITS format (Wells et al. 1981) but has been designed to meet the specific needs of the EPN. The format has proved so successful that we now advocate its use as a useful world–wide utility for pulsar data exchange. To aid implementation of the format, we have written a suite of freely available *Fortran–77* sub–routines which can be easily incorporated within existing software to read and write data in this format. Astrophysical applications of such a format currently being pursued by EPN groups include the establishment of a data bank of pulse profiles as well as simultaneous observations of pulsars by several European observatories.

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2. The EPN format

The underlying principles of the format result from a number of requirements. This was essentially a balance between the need for efficient data storage and providing sufficient information about the data for potential users. Specifically, the following requirements had to be met:

- **Operating system independence:** To make the data format as portable as possible between present and future operating systems, we have opted to use only ASCII–data throughout. We have arrange these data so that words are aligned over 80-byte boundaries, this simplifies inspection and printing of the files.
- **Completeness:** The data should contain all information for the identification of the source and the observing circumstances useful for further analyses of the data by others.
- **Compactness:** Descriptive information should not dominate the format. The measured values that form the bulk of a block of data are given as scaled four-character hexadecimal numbers, giving a dynamic range of up to 65536:1.
- **Versatility:** The format should be suitable for continuously sampled multi-channel filterbank search data, synchronous integrated and single–pulse data as well as processed data. In addition, we have designed the format, so that it can be used for observations of pulsars outside the radio regime i.e. variable units for the observing frequency and bandwidth, as well as

topocentric telescope coordinates which are time variable for satellite observatories. Space is left for more descriptors, future adaptations and expansions.

– **Simplicity and ease of access:** We describe a data format consisting of a standardised fixed-length header with a variable length data structure attached to it. The header fully describes the structure of the data, which is not changed within one file but can vary between files. In this way, it is possible to calculate the length of a data block within each file after reading its header. The file can then be opened for random access with fixed block length, faster than a sequential read.

Many of the above mentioned requirements were already met by a format in use at Jodrell Bank to which we made suitable modifications and extensions to make it more flexible.

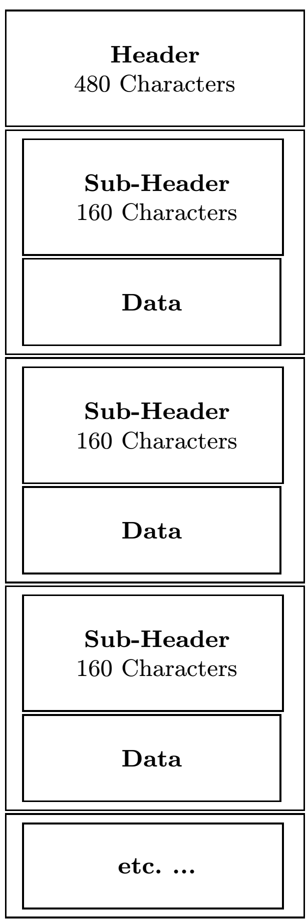

Fig. 1. Schematic representation of an EPN data block

Each EPN file consists of one or more EPN blocks. The basic structure of an EPN block is shown in Fig. 1. Each file has a common fixed length *header* followed by a number of individual *data streams* of equal length. The header describes the data, containing information on the pulsar itself, the observing system used to make the observation as well as some free-form information about the processing history of the data. The onus is on the site–specific conversion process to ensure correct conversion to the standardised entries and reference to common catalogues (e.g. the Taylor et al. 1993, catalogue of pulsar parameters). The full list of header variables is given in Tables 1 and 2.

The data streams themselves may be outputs of different polarisation channels, or individual channels (bands) of a filterbank or a combination thereof. In total, there may be $N_{\rm freq}$ data streams of i.e. different frequencies for each polarisation. Each data stream starts with a small, fixed length sub-header in front of the actual data values. The number of data streams and their length may vary between different EPN files, but is constant within each file. A character field and an ordinal number is provided for each stream for its identification.

3. Simultaneous observations of single pulses

Pulsars are, in general, very weak sources, typically requiring the addition of several thousand individual pulses with a large radio telescope equipped with sensitive receivers in order to attain a sufficiently large signal-to-noise ratio. The brightest pulsars are, however, strong enough so that individual pulses can be observed. These pulses are known to exhibit great variety in morphology and polarimetric properties from one pulse to the next (see for example Lyne & Smith 1990). It is presently unclear whether the same features in the individual pulses are present at different observing frequencies. One of the current research topics being carried out by EPN is a multi-frequency study of single pulses. The project requires the pulses observed at different telescopes to be time-aligned and thus the format described above has an ideal application in this project. After conversion of the data into this format, the time alignment of the pulses and subsequent statistical analyses is a relatively straight-forward procedure. As an example, a set of pulses from PSR B0329+54 observed simultaneously at Bologna (410 MHz), Jodrell Bank (1.404 GHz) and Effelsberg (4.850 GHz) are shown in Fig. 2. The pulses show a remarkable similarity at these three frequencies, although counter examples are also observed. Full results of this study will be published shortly.

4. The EPN pulse profile archive

As well as being used for data interchange between EPN members, the common format forms the basis of a pulse profile archive presently being maintained at the Max-Planck-Institut für Radioastronomie in Bonn. The idea of the archive is to build up a useful collection of pulse profiles which anybody with access to the *Internet* can use. Presently, around 2500 pulse profiles are stored in this format. The profiles

Table 1. A description of the EPN format variables

Position	Name	Format	Unit	Comment
1	version	A8		EPN + version of format (presently EPN05.00)
9	counter	I4		No. of records contained in this data block
13	history	A68		comments and history of the data
81	jname	A12		pulsar jname
93	name	A12		common name
105	$P_{\rm bar}$	F16.12	s	current barycentric period
121	DM	F8.3	pc cm^{-3}	dispersion measure
129	RM	F10.3	rad m^{-2}	rotation measure
139	CATREF	A6		pulsar parameter catalogue in use
145	BIBREF	A8		bibliographical reference key (or observer's name)
153		8X		blank space free for future expansion
161	α_{2000}	I2,I2,F6.3	hhmmss	right ascension of source
171	δ_{2000}	I3,I2,F6.3	ddmmss	declination of source
182	telname	A8		name of the observing telescope (site)
190	EPOCH	F10.3	day	modified Julian date of observation
200	OPOS	F8.3	degrees	position angle of telescope
208	PAFLAG	A1		A = absolute polarisation position angle, else undefined
209	TIMFLAG	A1		A = absolute time stamps (UTC), else undefined
210		31X		blank space free for future expansion
241	$x_{\rm tel}$	F17.5	m	topocentric X rectangular position of telescope
258	$y_{\rm tel}$	F17.5	m	topocentric Y rectangular position of telescope
275	$z_{\rm tel}$	F17.5	m	topocentric Z rectangular position of telescope
292		29X		blank space free for future expansion
321	CDATE	I2,I2,I4	d m y	creation/modification date of the dataset
329	SCANNO	I4		sequence number of the observation
333	SUBSCAN	I4		sub–sequence number of the observation
337	$N_{\rm pol}$	I2		number of polarisations observed
339	$N_{\rm freq}$	I4		number of frequency bands per polarisation
343	$N_{\rm bin}$	I4		number of phase bins per frequency (1-9999)
347	$t_{\rm bin}$	F12.6	μs	duration (sampling interval) of a phase bin
359	$t_{\rm res}$	F12.6	μs	temporal resolution of the data
371	$N_{\rm int}$	I6		number of integrated pulses per block of data
377	$n_{\rm cal}$	I4	$t_{\rm bin}$	bin number for start of calibration signal
381	$l_{\rm cal}$	I4	$t_{\rm bin}$	length of calibration signal
385	FLUXFLAG	A1		F = data are flux calibrated in mJy, else undefined
386		15X		blank space free for future expansion
401		80X		blank space free for future expansion

themselves have usually already been, or about to be, published so that full credit for any subsequent use via the database can go to the contributing authors. The archive has the following URL address: *http://www.mpifr-bonn.mpg.de/pulsar/data/*. Authors are encouraged to make their data available to this archive and should contact Duncan Lorimer (e-mail: *dunc@mpifr-bonn.mpg.de*) if they wish to do this.

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Appendix

A. Format compatible software

To incorporate the capability to read and write data in this format within existing analysis software, a simple routine exists which can read and write data in this format. In addition, we have written some sample programs which can plot the data and display the header parameters. The software are written in *Fortran—77* and have been packaged into a single UNIX tar file which is freely available via the *Internet*. To down-load the package, log into the anonymous ftp area: **ftp.mpifr-bonn.mpg.de**, with the username **anonymous** using your complete E–mail address as the password. Once logged in, issue the following commands:

Table 2. The sub-header variables. $^*\Theta(x)$ is the Heaviside–function: $=1$ if $x \geq 0$ and $=0$ elsewhere

Position	Name	Format	Unit	Comment
481	IDfield	A8		type of data stream (I, Q, U, V etc.)
489	$n_{\rm band}$	I4		ordinal number of current stream
493	$n_{\rm avg}$	I4		number of streams averaged into the current one
497	f_0	F12.8		effective centre sky frequency of this stream
509	U_f	A8		unit of f_0
517	Δf	F12.6		effective band width
529	U_Δ	A8		unit of Δf
537	$t_{\rm start}$	F17.5	μs	time of first phase bin wrt EPOCH
554		7X		blank space free for future expansion
561	SCALE	E12.6		scale factor for the data
573	OFFSET	E12.6		offset to be added to the data
585	RMS	E12.6		rms for this data stream
597	$P_{\rm app}$	F16.12	s	apparent period at time of first phase bin
613		28X		blank space free for future expansion
641	Data(1)	I4		scaled data for first bin
$4(N_{\rm bin}-1)+641$	Data($N_{\rm bin}$)	I4		data for last bin of stream
$640+N_{\rm records}*80$				end of first stream, $N_{\rm records} = {\rm INT}(N_{\rm bin} \cdot 0.05) + \Theta((4N_{\rm bin} {\rm mod}\ 80)-1)^*$

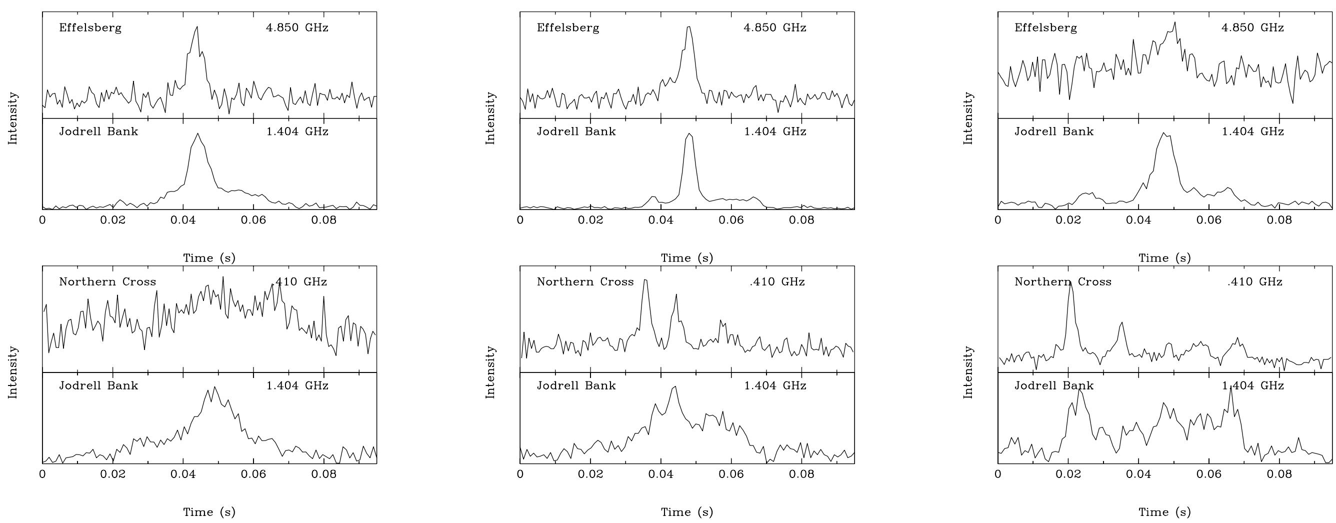

Fig. 2. Time-aligned single pulses for PSR B0329+54 observed simultaneously at Effelsberg (4.850 GHz) and Jodrell Bank (1.404 GHz) shown in the upper panel and at Bologna (410 MHz) and Jodrell Bank (1.404 GHz) in the lower panel. The data were processed using the EPN format

```
cd pub/pulsar
binary
get epnsoft.tar.gz
```

Alternatively, the file can be down-loaded from the EPN *Internet* home-page:
http://www.mpifr-bonn.mpg.de/pulsar/epn/.

To uncompress and extract the contents of the tar file on a UNIX operating system, issue the commands:

```
gunzip epnsoft.tar.gz
tar xvf epnsoft.tar
```

The present package contains some sample data and two example programs — "plotepn" and "viewepn" which plot and view EPN files respectively. The ASCII file **00README** in this packages gives further details of the software and how to use it.

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