Alternative Log Input to the VLBA Correlator for Space VLBI Observations

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Introduction

A comprehensive record of observational conditions — pointing coordinates, equipment setup, calibration measurements, *etc.* — is an all but universal requirement in observational astronomy, or indeed in any empirical science. In VLBI, where correlation is an essential part of the observational process, but is performed off-line under exacting circumstances, the record-keeping requirement is unusually stringent. Such records also are essential in post-correlation analysis, notably for calibration. A set of auxiliary data of this type, time-tagged and ordered chronologically, is commonly called a "log", and the term is used in that sense throughout this document.

A VLB interferometer element in Earth orbit presents some unique complications for this log concept. The Space VLBI "station" is not unitary; it includes the spacecraft, several ground telemetry stations, one or more ground command stations, and a ground operations group. On the spacecraft, under control of the command station, the antenna is pointed, the observing band selected, and baseband-conversion mixers and filters set. The telemetry stations insert time tags and operate the recording systems; a given station may track the spacecraft for a period as short as a few hours before handing off to another station. With this fragmentation of activities, the Space VLBI element does not conform well to the "station" concept on which conventional log structures, and indeed correlator architectures, are designed. Nevertheless, it is possible to specify log entries which must be generated at each of these different elements of the Space VLBI system.

This document proposes such a specification, including detailed definitions of all entries required to process recordings derived from the Space VLBI "station" at the VLBA correlator. The entries all carry time tags which facilitate the assembly of logs received from all participating mission elements into a single, chronological stream of entries essentially indistinguishable from that for a ground-based station.

Scope

The general case of logs transmitted between the various types of equipment in use throughout the global VLBI community is quite complex. There are at least five different data-acquisition systems to be considered: Mark 3A, VLBA, VSOP, S-2, and Mark 4 — some with radically different instrumental parameters, and operated by almost as many different control systems running on different computers. And there are eight different correlator designs: Mark 3A (at three different institutions), K-3, Block 2, VLBA, VSOP, S-2, AT/LBA, and Mark 4. (The obsolete Mark 2 and Mark 3 systems have been omitted from these lists.)

A considerable simplification can be obtained by noting that the VSOP and S-2 recording systems are fundamentally non-interoperable with the three mutually-compatible Mark 3A, VLBA, and Mark 4 systems, and that all current plans for joint observations using combinations of incompatible systems foresee using intermediate tape-format translator/copiers to bring all recordings into a single system. The translation process will have to be driven by a log accompanying the input recordings, *and must produce a revised log with different recorder parameters appropriate to the output recordings.* This log conversion is the responsibility of the operators of the tape-format translator systems.

Under this assumption, the scope of the present specification can be limited to the mutually (backward) compatible Mark 3A, VLBA, and Mark 4 recording systems, and to correlators designed to read such recordings directly.

Non-log auxiliary data types which also are required for correlation of Space VLBI observations are not addressed in this specification. Two specific types, the spacecraft ephemeris and the phase-transfer-link timing corrections, are the subject of separate specifications.

SNAP Logs

The VLBA has implemented station logs in the form of binary monitor data transmitted directly to the Array Operations Center, generally in real time. Although this format and method have been used successfully by at least three non-VLBA telescopes, they are not considered to be generally suitable for use by non-VLBA telescopes and other space VLBI mission elements.

NRAO personnel working on the VLBA correlator suggested early in the project that Mark-3-type "SNAP logs" appeared to be a suitable basis for an alternative log format for non-VLBA telescopes. In recent years this interface has been implemented and used with reasonable success. SNAP, an acronym for "Standardized Notation for Astronomical Procedures", is *per se* a language (developed in 1978 by A. R. Whitney and N. R. Vandenberg) for describing observing schedules, not logs. However, its specifications include monitor responses which the control system must return in the acknowledgement of each command. The Mark III/IV Field System, and most of its offshoots, records these responses, along with time tags, to form what will be called "SNAP logs" in this document.

The Field System is presently evolving toward full VLBA and Mark 4 compatibility. While this is an important, indeed necessary condition for participation of most non-VLBA radio telescopes in VSOP observations, it does mean that no current SNAP documentation can be referenced here. Nevertheless, this specification is intended to be self-contained, and no such reference should be necessary in order to understand or implement it.

Specification — General

The present specification can be described as "SNAP-like". Because it is intended to be written by installations which are neither operating a radio telescope nor running any version of the Field System, several simplifications of the format have been made. And since the Field System is presently under active development as mentioned above, it has been necessary to anticipate somewhat the final form of some of the entries.

The definitions are generally a subset of standard SNAP formats, to avoid requiring voluminous and (for present purposes) unnecessary data be included, while maintaining as much compatibility as possible with the SNAP log interpreter already in use at the VLBA correlator. Additional entries, specific to the Space VLBI application, have been defined where necessary.

Separate sections below detail the command/response log entries which each Space VLBI mission's Spacecraft Operations Group (SOG) and the ground telemetry stations, respectively, *must* include in their logs. Additional, *distinct* entries (*i.e.*, with entry names *not* appearing in this specification) may be included and will be ignored.

Some telemetry stations may be able to, and choose to, include in their logs all or most of the entries for which the SOG normally is responsible. This combined log is intended for direct use at a correlator in support of rapid-turnaround tests. The SOG retains the overall responsibility for verifying or correcting any such entries in the logs delivered as part of routine Space VLBI observations.

Format. The entire log file may contain only ASCII characters. It is divided into lines, of maximum length 80 characters, by newline characters (hexadecimal 0D). Upper or lower case alphabetic characters may be used interchangeably, with a single exception, noted where it occurs.

All log entries consist of three basic fields, starting at the beginning of a line. Fields are separated by slash characters (`/`). Although true SNAP logs use a variety of field-separator punctuations to indicate the origin of a given entry, it is possible for the purposes of this specification to ignore these distinctions.

The first field is a 13-digit year/day/time field, represented as `yydddhhmmssxx` in the definitions. The `yy` sub-field specifies the last two digits of the year, `ddd` the day-of-year (with January 1 as day 1, an archaic but SNAP-standard form of the date), and `hhmmssxx` the time in hours, minutes, seconds (including a two-digit decimal fraction). The time so encoded is the UTC at which the new parameter values given in the entry first apply.

The second field is the name of the entry.

The third field consists of zero or more parameters, separated by commas if two or more are present. These parameters, represented in the definitions below by a mnemonic word or phrase in `<angle-brackets>`, are identified strictly by position in the sequence. For compatibility in a few exceptional cases, it has been necessary to specify dummy parameters as place holders. (Dummy parameter values may be any alphanumeric string of maximum length 8 characters, including a zero-length null string.)

The standard SNAP command responses often include more parameters than are specified here; those omitted are not relevant for the present purposes. Additional parameters may appear following those required by this specification.

The function, format, and units of each parameter are described in the definition. Parameters which represent numerical values may include only digits and a decimal point. Parameter values which are character strings in general need *not* be enclosed in any kind of delimiters, aside from the required commas, except that strings containing embedded blanks or commas must be enclosed in paired single (') or double (") quotes.

Comments. Comments, which may appear at any point in the log, deviate somewhat from this format. They are recognized by a double-quote character (") immediately following the time tag, and may contain any other text through the end of the line.

Merging of Entries. *The Spacecraft Operations Group is responsible for producing the log file delivered to the VLBA correlator,* by merging the entries for which it has specific responsibility, listed in the following section, with those produced by all the ground telemetry stations, as defined in the subsequent section.

Scope and Context of the Log. The SOG is given substantial latitude in choosing the breakpoints between succeeding log files. Typical logs might correspond to approximately one day's operations, or to a single observing program. Numerous short log files will become operationally cumbersome, but may be unavoidable if longer files become too large; on the other hand, logs could extend to cover several days if that is both feasible and convenient for the SOG.

Each log file must re-establish the complete instrumental context existing at the end of the preceding log, by re-issuing any entries which continue. Additionally, the context of telemetry-station parameters must be re-established at the beginning of each new tracking session (as defined in a later subsection) by issuing new entries of certain types, listed at the head of that section. This requirement may make it convenient to break succeeding log files between tracking sessions, but it is not compulsory to do so. Log file breaks which do occur during a tracking session may *not* occur while the recording being logged is in progress.

Timing of Entries. In general, any of the defined log entries should appear each time any of the parameter values being logged change on the spacecraft or at a telemetry station. There are some exceptions, noted in comments appended to the definitions, for parameters which should be logged when a continuously varying value changes by an amount deemed to be significant, or at specific intervals. It is assumed that the control systems writing the log entries will control their equipment in a rational sequence, with setup actions preceding their logical successors, so that the corresponding log entries also appear in a rational sequence.

SRT Schedule Definitions. The phrase "SRT Schedule" is used in a specific sense in some of the detailed log entries below. It refers to the "Space Radio Telescope (SRT) Schedule File", distributed by the SOG to all mission elements, as specified in reference [1]. The term "tracking session" is used here in the sense defined in Section 1.2 of that document.

SPECIFICATION — SPACECRAFT OPERATIONS GROUP

The SOG has primary responsibility for logging most actions and measurements on the spacecraft, including all those derived from spacecraft telemetry whether received via the command up/downlink, or embedded in the signals received at the downlink stations and forwarded to the SOG. The SOG must also verify or correct any entries listed in this section which may be included in a ground telemetry station's log (as described under "Specification — General" above).

`yydddhhmmssxx/BBC<code>/<frequency>,<dummy>,<usb-bw>,<lsb-bw>,<polarization>`

`<code>`	BaseBand Converter ID code. For purposes of this specification, it is a completely arbitrary single alphanumeric character, used only to match against the `<code>` parameters in the TRACKFORM entry.
Comment:	The `<code>` "parameter", deviating from the normal format convention, formally is incorporated as part of the entry name.
Comment:	Since the TRACKFORM entry is produced by the ground telemetry stations, some convention for the `<code>` parameters must be established. It is suggested that the channel ID given in the SRT schedule be used.
`<frequency>`	Total ("signed sum") local oscillator frequency, in MHz, of all frequency conversions between RF and the final baseband(s) delivered by this converter.
`<dummy>`	Unused positional parameter.
`<usb-bw>`	Filter bandwidth, in MHz, applied to the USB channel delivered by this converter.
`<lsb-bw>`	Filter bandwidth, in MHz, applied to the LSB channel delivered by this converter.
`<polarization>`	State of polarization of the RF signal processed through this converter, either `L` for left-circular or `R` for right-circular.
Comment:	There must be one BBC entry for each active baseband converter.
Comment:	Some of the information required for this entry is specified implicitly via the CNFIG configuration code in the SRT Schedule.

`yydddhhmmssxx/FORM/<type>,<rate>,<mode>,<roll>`

`<type>`	Format type. Only value currently permissible for Space VLBI is `v`, for VLBA format.
`<rate>`	Sample rate, in Msample/sec.
`<mode>`	"Effective VLBA formatter mode", *i.e.*, as required for correct *deformatting* in the VLBA correlator. Possible values are `1:1`, `1:2`, or `1:4`.
`<roll>`	Barrel roll state. Possible values are `16:1`, `8:1`, or `off`, for the 16- and 8-track rolls, or for no roll, respectively.
Comment:	Some of the information required for this entry is specified implicitly via the CNFIG configuration code in the SRT Schedule.

`yydddhhmmssxx/OBSCODE/<code>`

`<code>`	The "observation code" assigned to the observations which follow. The code must consist of exactly *five* alphanumeric characters. For VSOP, the first character must be the letter `V`.
Comment:	OBSCODE must precede all entries for the observations to which it applies.
Comment:	It is expected that the SOG will assign observation codes to facilitate proposal handling, reviewing, and scheduling. A given proposal may result in one or more, potentially many, "observations", each a contiguous time interval during which the spacecraft is dedicated to the goals of that proposal, and each having a unique OBSCODE.

`yydddhhmmssxx/SOURCE/<name>`

`<name>`	Name of the source being observed. *The name string must be given exactly as it appears in the SRT Schedule* and should not exceed twelve characters. It may not contain any blanks (including leading or trailing blanks) or commas.
Comment:	Only the *name* of the source is required. The SNAP command response also includes the source position (and epoch) used by the Field System, and these may be included within the format rules of this specification. *Any coordinates specified in the* SOURCE *entry will be ignored by the VLBA correlator,* which takes its positions from a separate database.

Specification — Ground Telemetry Stations

The telemetry stations' log entries are concentrated on the recording performed there. If feasible and desirable, they may include as well any of the entries listed in the preceding section (as described under "Specification — General" above).

It is essential to preclude ambiguous entries resulting from possible overlapping in time of activities at different ground telemetry stations. *All events logged at a ground telemetry station must fall within its tracking session,* as defined in Section 1.2 of the SRT Schedule specification [1]. An acceptable alternative is to provide false time tags, shifted to simulate observance of this rule, as long as the sequence of events is not altered.

To establish the correct instrumental context, the TSID entry which indicates the beginning of a new tracking session must be followed by new PASS, TRACKFORM, and VSN entries (in arbitrary order), before any ST entry occurs.

`yydddhhmmssxx/BIT_DENSITY/<density>`

`<density>`	Longitudinal bit density at which the tape is recorded, in *total* bits per inch, *i.e.*, including parity and framing overhead. Possible values are `56700` for high-coercivity D1K-compatible "thin" tapes, or `34020` for the older, lower-coercivity "thick" tapes.

`yydddhhmmssxx/ET/`

Comment:	ET must be issued when tape motion stops.

`yydddhhmmssxx/PASS/<dummy>,<dummy>,<dummy>,<head-position>`

`<dummy>`	Unused positional parameters.
`<head-position>`	Nominal headstack position, in microns.
Comment:	The set of possible headstack positions, and the appropriate sequence of use, are specified in separate documents. Reference [2] is the specification for VSOP.

`yydddhhmmssxx/ST/<direction>`

`<direction>`	Direction of tape motion, either `FOR` for forward or `REV` for reverse.
Comment:	ST must be issued when tape motion starts, or speed changes.

`yydddhhmmssxx/TAPE/<dummy>,<footage>`

`<dummy>`	Unused positional parameter.
`<footage>`	Current reading of the tape transport footage counter.
Comment:	TAPE must be issued *before* each ST, and *after* the tape has stopped after an ET entry.

`yydddhhmmssxx/TRACKFORM/<first-track>,<bit-stream>,...`

`<first-track>` Track assigned to the bitstream identified in the following parameter. The *first* recorder track assigned is indicated; the remainder are assumed to be assigned using the standard VLBA convention.

Comment: The set of possible track assignments, and the appropriate sequence of use, are specified in separate documents. Reference [2] is the specification for VSOP.

`<bit-stream>` Bitstream to be recorded on the specified track (and any others incorporated through the standard VLBA convention). A bitstream is a time sequence of more- or less-significant bits derived by sampling a single baseband channel, and is identified by a concatenation of three one-character sub-parameters: `<code><sb><bit>`.

`<code>` BaseBand Converter ID code, which must match one of the `<code>` parameters in BBC entries.

`<sb>` Sideband of the specified BaseBand Converter which delivers this channel, either `U` for upper or `L` for lower sideband.

`<bit>` Significance of the bit delivered by the sampler for this channel, either `S` for the more significant (or only) bit, or `M` for the less significant bit.

Comment: There must be one pair of TRACKFORM parameters for each active bitstream. They may appear sequentially within a single TRACKFORM entry, or be spread over two or more entries appearing contiguously in the log.

`yydddhhmmssxx/TSID/<station>,<spacecraft>`

`<station>` Identification code of the telemetry station originating subsequent entries, as used in the SRT Schedule.

`<spacecraft>` Identification code of the Space VLBI spacecraft whose data are being recorded, as used in the SRT Schedule.

Comment: TSID *must be the first entry at the beginning of each new tracking session included in the log file.*

`yydddhhmmssxx/VSN/<tape-vsn>,<recorder>`

`<tape-vsn>` Tape volume serial number. Must be an 8-character string. Alphabetic characters included in the serial number must be given in the same case (typically upper case) in which they appear on the physical tape label.

`<recorder>` The number of the tape recorder unit at the telemetry station on which the tape is mounted. Each telemetry station's complement of VLBA-compatible recorders must be numbered sequentially, starting at 1.

Comment: VSN must be issued whenever recording begins on a new tape which is to be sent to the VLBA correlator. In general, only one such tape will be recorded at a time. If two simultaneously-recorded tapes are both sent to the VLBA correlator, *each must have its own separate log file,* with the correct VSN entry.

References

[1] J. Ulvestad, A. Wiercigroch, Y. Murata, M. Popov, & L. D'Addario, "Space Radio Telescope (SRT) Schedule File", Version 3.0, 1995 September 15.

[2] J. S. Ulvestad & J. D. Romney, "Recording VSOP Data (Mode 128-2-2) on VLBA Tapes", Version 2.0, 1995 December 17.