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COMPARISON OF DECODER DESIGNS -- VSOP MODE

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In this note, I summarize the properties of the downlink data decoders used at the three types of tracking stations supporting VSOP. These include the ISAS station at Usuda, Japan; the three stations (of identical design) belonging to the NASA Deep Space Network (DSN); and the NRAO station at Green Bank, WV. Details were obtained from discussions with each of the designers [1,2], from review of the documentation available to me [3], and from tests conducted on the Usuda equipment at Sagamihara, Japan [4].

Format parameters (see [5] for further details):

Frame length	640,000 bits	5.0 msec @ 128 Mb/s
Header length	96 bits	
Sync word length	32 bits	
Transmission format	QPSK modulation, 64 MHz clock, differential encoding	

SPECIFICATION SUMMARY TABLE

	NRAO	DSN	ISAS (Usuda)
Sync detection (each frame)	tolerance=0b window=64b	tolerence=4b (track) 0b (search) window=64b	tolerence=2b window=32b
Missed sync	probation: 1 frame then PRN to tape 16x -> search (no bad to tape)	probation: 2 frames then PRN to tape 5x -> search (up to 3 bad to tape)	no action 3x -> search (3 bad to tape)
Re-sync	Immediate Previous fr:PRN->tape Slip size logged with resolution of 8b.	Immediate Previous fr:PRN->tape Sign of slip logged.	Not possible
Search mode	Delete window 16x sync det -> set window; data to tape; track mode.	Delete window; tol=0 1 sync det -> set window; tol=4. Next sync det -> data to tape; track mode.	Set tape flag: VSOP:stop rec VLBA:no action 1 sync det -> set window 3x sync det initialize; resync; clr tape flag: VSOP:resume track mode. 3x missed sync-> delete window.

Notes to table:

1. "Tolerance" is the number of bits of the 32 bit sync word that are allowed to be in error while still regarding the sync word as being detected.

2. "Window" is the number of bits, centered at the expected sync word

location, during which the decoder attempts to detect the sync word. A window width equal to the sync word length (32b) implies that data is ignored by the sync detector except at exactly the time that the sync word is expected.

3. "PRN" means pseudo-random noise. The NRAO and DSN decoders substitute PRN for the data of each frame when their algorithms imply that the data's timing has slipped (re-sync) or the timing cannot be determined with certainty (excessive missed sync words).

4. All designs incorporate a "search mode" and a "track mode." In search mode, the window is not used and the sync detector is always active ("delete window"). In the DSN design, the sync dectection tolerence is 0b in search mode, but 4b in track mode; for the others it is the same in both modes. All designs are initialized to search mode, and they switch to track mode after some number of successful sync detections; all revert to search mode after some number of missed sync detections. Note that, for a given bit error rate, the probability of missing a sync detection depends on the detection tolerance and the window size, and these differ among the designs; the number of good/missed detections required for a change of mode also differs among the designs, as shown in the table.

5. "Probation": In the NRAO and DSN designs, the data is buffered before it is sent to the tape. This allows a decision on whether a given block of data is good to be deferred until the buffer must be written out. Following each frame, if the next sync word is detected at the expected time, then all bits of that frame are assumed to have the correct timing, and the data will be written to the tape (marked "good"); if the sync word was detected at the wrong time, then all bits of the frame will be replaced by PRN when that frame is written out (marked "bad"); but if the sync word is not detected at all, then the data is considered "on probation," with the decision to be made later. If a succeeding sync word is detected at the expected time, then all frames on probation are marked "good"; if a succeeding sync word is detected at the wrong time, then all frames on probation are marked "bad." If no succeeding sync words are detected at the time that a frame on probation must be written (because the buffer is full), then the NRAO design marks it as "bad" but the DSN design marks it as "good." The NRAO design has a buffer long enough for 1 frame to be on probation at a time; the DSN design allows 2 such frames. On the other hand, the DSN design will switch to search mode after 5 missed sync words, so this limits the number of bad frames that might be marked as good to no more than 3.

6. "Re-sync" means that the sync word was detected at other than the expected time, so recent data contains a timing slip and it is necessary to re-synchronize future data.

6a. The NRAO and DSN designs do this immediately by sending the correct number of bits (of PRN) to the tape for each frame, even if the number of bits received on the link was smaller or larger than normal.

6b. The Usuda design enters search mode after failure to detect sync in three successive frames; re-syncing is possible only from search mode. While in search mode, recording on VSOP tape is stopped; this limits the number of bad frames that might be recorded to no more than 3, and these are at the end of a logical record, so they can be ignored upon playback. After re-sync and resuming track mode, a full timing re-initialization is done and then recording is resumed. If the station was recording on VLBA tape, recording cannot be immediately stopped. After re-sync, the full re-initialization of timing is done as with VSOP tape, but this takes several seconds since it includes re-configuration of the VLBA Formatter. With either recorder, the time of entering search mode and the time of the re-initialization (clock setting event) are logged, and the interval between them is flagged as bad.

7. In the NRAO design, the precise tape time of each frame that has been replaced by PRN can be deduced from the station's internal log. At present this information is not further processed, but it is available if needed.

8. In many cases, the numerical parameters given in the table (such as the sync detection tolerance or the number of missed syncs allowed before switching to search mode) are programmable and may easily be changed if desired. I have given the values currently planned for VSOP operation.

9. The NRAO and DSN designs can also handle data in RadioAstron format. Numerical parameters are then generally different, and additional features become active. Details will be considered in a separate document.

DISCUSSION

Study of the above information shows that a very brief loss of signal which results in no bit slip is tolerated by all designs with no effect on the data flow. That is, if the clock recovery circuit is able to "flywheel" during the loss of signal to an accuracy of less than one data bit, then no re-sync will be needed.

For the Usuda station, if the dropout extends for 3 frames or more, then a complete re-initialization sequence will be initiated.

For the NRAO station, the data will be replaced by PRN after 1 frame, but the sync detector will continue in track mode (window active) for another 15 frames before switching to search mode; even then, it continues attempting to flywheel so that if the sync word is ever detected at the expected time, then no re-sync occurs. After sync is re-acquired, an integral number of standard frames will have been written to the tape; thus, there is no timing slip on the tape unless it is a complete frame or an integral number of frames. This can be checked by offline software on the basis of the frame counters in the headers. The frame counters have a net modulus of 400, corresponding to 2 sec of data; so, after checking the frame counters, the amount of any timing slip is known modulo 2 sec. The clock recovery oscillator is expected to be able to flywheel to an accuracy of 1 part in 1e4, so this method allows recovery from dropouts lasting up to (2sec)/(1e-4) = 20000 sec. Such a recovery is effected without the need for re-initialization (clock setting event).

For the DSN stations, it is uncertain whether the frame counters can be used for offline timing recovery following a dropout. But the clock recovery oscillator is expected to provide flywheeling to higher accuracy, perhaps 1 part in 1e6, so no timing slip occurs on the tape (i.e., recovery occurs automatically) for dropouts up to (5msec)/(1e-6) = 5000 sec.

Notwithstanding the above recovery methods, the NRAO and DSN stations will carry out a complete re-initialization after some types of signal dropout. For example, if the two-way timing link is lost and then re-acquired, a re-initialization may be advisable even if the data clock is maintained, since a timing slip unknown size (although perhaps less than one data clock) may have occurred. Details are TBD. In such cases, correlators should also re-initialize their timing, and the need for this should be signalled by starting a new DELTAT table in the time corrections file [6]. Conversely, if the timing can be recovered completely (to a small fraction of a cycle at the observing frequency), then the DELTAT table should be continued, with a discontinuity in the time correction value if needed.

REFERENCES

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