National Radio Astronomy Observatory

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To: VLBA Data Acquisition Group

From: C. Janes

Subject: Accelerated Thin Tape Test II

Introduction

NRAO has transferred approximately 400 thin tapes to the new Acrometal glass self-packing reels since the first Accelerated Thin Tape Test was wrapped up in June 1993. A decision was made to commission a second test to determine the durability of:

1) the new Sony and 3M tapes on the new reels,
2) a sampling of the survivors from the first test transferred to the new reels, and
3) a sample of Ampex tape reformulated with revisions in the glass transition temperature and the slitting.

Like its predecessor, Tape Test II called for shuttling the tape back and forth for 8 hours at 330 ips and 10" of water vacuum followed by a slow speed "wind test." However, the tests were all conducted at the AOC instead of at remote sites; shipping was simulated to reduce cost and to save time. Because a tape in normal use is recorded, shipped, and then played back, the tape had to be shuttled and "shipped" twice to represent a test cycle.

The goal was to perform 35 test cycles on each tape in the test to represent 5 years of useage. Only 2 years of equivalent testing was completed, but enough to make some useful observations.

Test philosophy

The aim of any accelerated test is to quickly obtain data which yield desired information on product life and performance under normal use. Normal useage for the NRAO application currently calls for passing the magnetic tape back and forth for up to 12 passes, each round trip pass taking about 60 minutes at 270 ips, for a total of up to 12 hours of recording. The tape tension currently used for observing with thin tape is imposed by a vacuum of 10" of water, though tests are planned to reduce the tension on thin tape in the future. After the recording session, the tape is shipped to the correlator where it is passed back and forth under similar conditions for the same length of time. The tape is then degaussed and shipped back to a recording site.

The speed of the tape during the test was increased to 330 ips which slightly reduces head wear and slightly overstresses the tape. Shuttle time was reduced from 12 to 8 hours for practical reasons. Overstressing was further introduced in the wind test where the tape was passed once from the self-packing reel to a

non-self-packing take-up reel at 80 ips and 15" of water vacuum. The theory is that if the tape can survive a reasonable amount of overstressing, it is more likely to survive normal use. As well, an incipient problem with the tape pack is more likely to show up during the wind test. The wind test was conducted after each shuttle session, twice per "cycle." The tape was rewound at 330 ips and 10" of water vacuum after the wind test in preparation for the simulated shipping cycle.

The shuttling portion of the thin tape test was initially performed at 10" of water vacuum, but was changed to 7.5" on October 14, so as not to disturb the contour of the correlator playback drive heads which were being used at 7.5" to read thin tape. The last 5 cycles of tape testing was done at 7.5".

Shipping normally includes changes in humidity, temperature, and barometric pressure in addition to exposure to vibrations and impact. It was decided that problems with the tape pack would be most likely introduced by impact, so that the shipping simulation was reduced to two drops of the tape in the shipping canister, one on each side of the container, falling flat, from a height of 24". A fall from that height can introduce impact forces to the tape pack of up to 250 g based on tests conducted at the AOC. Impact sensors placed on tapes actually shipped show only an occasional impact of 300 g or more, but an impact of 200g or more 1/3 of the time and an impact of 50 g or more on almost every shipment. There was neither the time nor the budget to actually ship the test tapes after each shuttle session. Degaussing was not included.

The accelerated test did not include any "elephant" test to determine survivability limits of the tape, such as applying temperature extremes, tension limits, edge wear from misaligned tape drives, or abnormally dirty operating conditions. H. Hinteregger applies a "torture" test by running the tape between self-packing reels at 20" of water vacuum 24 hours per day without cleaning the drive until the tape fails. Such a test is useful for measuring the relative durability of tape from different vendors, but does destroy the tape.

Although three glass reels have broken so far, one in shipment, one from being dropped, and the third under unknown circumstances, a durability test for the reels was not included.

Neither did the accelerated test include any measure of signal recovery. The experience at Haystack is that the magnetic coating is the least of the problems when measuring tape survivability.

Tape Test I did not include a comparison with thick tape. The question is, if thick tape were exposed to the same conditions would it have survived? Thick tape also bumps up, breaks, and shifts so that edges become exposed, though much less readily. Some of the handling and alignment errors that have caused problems with thin tape may well have damaged thick tape, too. To counter this, a thick tape was introduced into Test II as a control.

The number in the test sample was primarily imposed by limitations in time, manpower, and drives available for the test,

as well as by demands for tape in the supply channel.

A tape failure is defined as a mechanical degradation of the tape to the point where it can no longer be used for data collection. It is generally believed that if a tape pack "bumps up" continuously under normal operating conditions that it is too stretched for reliable recovery of clock. In some cases a tape will bump up in the wind test, but recover during normal use, a tape condition A. Rogers calls "marginal" but not a failure. When a tape bumped up in Test II, an effort was made to recover the tape. If necessary, the tape was passed back and forth on non-self-packing reels at lower tension to relieve the bumps and inspect for a cause. If a tape recovered, it was returned to the test. This writer has not conducted tests to determine the damage threshold where data recovery is no longer reliably possible.

The tapes selected for the test and results so far

Ampex

Ampex provided 6 thin tapes for testing; four were tested at the AOC and developed spokes and/or bumps after a small number of test cycles. Hans Hinteregger received 2 of the Ampex tapes for testing. Both tapes failed a test in which they were shuttled continuously 24 hours per day at 10" of water vacuum and 270 ips, then checked with the wind test every other day. The drives were cleaned daily. One tape failed the wind test in a few days; the other in 2 weeks. Hans theorizes that Ampex has still not corrected a slitting problem which was shown to cause failure of tapes tested previously.

3M

Five 3M tapes were included in Thin Tape Test II, 3 from Accelerated Test I and transferred to new reels. All 3 of the previously tested tapes demonstrated problems during transfer: 2 bumped up but recovered, and 1 showed exposed edges. The one with the exposed edges had bumped up toward the end of Test I, but seems to have recovered now. The edge damage, however, was visible until the end of Test II.

One of the two new 3M tapes in the test was not included in testing until September 15. That tape left an abnormally large amount of black buildup on the vacuum column door during the second shuttle cycle, developed an "exposed edge" after cycle 9, and showed spokes after shipping in cycle 9. The spokes have not reappeared. The other new 3M tape had no problems.

Two of the old 3M tapes and one of the new ones developed minor spoking after a shipping test in cycle 6 to 9. Shortly thereafter the vacuum was dropped from 10" to 7.5" and the spoking did not recur.

Sony

Three Sony tapes from Test I were transferred to new reels,

and 2 new Sony tapes were selected for a total of 5. One of the new Sony tapes bumped up during the first test cycle, a problem traced to faulty threading of the tape during the initial transfer to a self-packing reel. 2000' of the tape was badly damaged and resisted recovery efforts; that part of the pack was removed. The second new Sony tape showed spokes after the shipping test in the 6th cycle but recovered.

One of the Sony tapes from Test I had exposed edges after the transfer to the new reel and spokes appeared. The tape has recovered from the spokes, but an exposed edge is still present. Of the remaining two old Sony tapes, both developed spokes as explained in the next paragraph.

Two of the old Sony tapes and one of the new ones developed spokes during cycle 6 to 8. An exposed edge occurred on one of these at the same time; the edge continued until the end of the test. As with the 3M tapes, the vacuum was dropped from 10" to 7.5" and the spokes did not recur.

The damaged tape edge / flange forcing problem

Now that the edge-melting problem with thin tape appears to be solved, the single biggest problem is the mechanical damage that occurs to a tape edge when a very small number of tape layers apparently shift with respect to neighboring layers. The exposed edges are easily crushed by the self-packing reel flanges, especially after the reel band is installed. The exposed-edge problem occurred during Test I primarily to 3M tapes and was thought to be caused by shifting of the tape pack during shipment when the reel flanges failed to hold a tight pack. The separation of the flanges in one case was found to be in excess of specification. Another proposal blames the problem on a higher friction coefficient of the 3M back coating.

During transfer of the new 3M and Sony tapes to Acrometal reels, the flange forcing and exposed edge problem occurred exclusively with 3M tapes at about the 5% level. With Test II the problem has occurred on tapes from all 3 vendors, has occurred on reels carefully checked to be within specification, and appears to have occurred independent of the shipping cycle.

Contrary to conclusions implied in VLBA Acquisition Memo #364 that the exposed-edge problem was catastrophic, several tapes seem to be surviving damaged edges satisfactorily. These tapes have one or more edges that are visibly deformed, but bumps and spokes have not formed in the tape pack. To be thorough, tapes with exposed or folded edges should be tested for signal recovery at high bit density and/or tested to the life limit to see if the exposed edge eventually leads to pack failure.

Four tapes that demonstrated the flange forcing and/or exposed edge problem during the initial transfer to self-packing reels were shipped to Hans Hinteregger for evaluation. Hinteregger found that at high speed, the tape can tend to pack toward one side leaving a gap between the other side of the tape pack and the reel flange. In extreme cases, the tape pack scatter increases with speed forcing the flanges on both sides away from

the pack. To counter the problem, Hinteregger recommends lowering tape tension in normal operation to at least 7" of water vacuum, and to rewind at least problem tapes at 160 ips before shipping. Indeed, the vacuum used for Test II was dropped from 10" to 7.5" on October 14; and several tapes that demonstrated minor spoke and exposed edges just before the vacuum change showed no further problems for the remainder of the test.

At least four of the new 3M tapes have been removed from use permanently because of problems that originated with exposed edges during the initial tape transfer. About 1 dozen more remain to be tested.

Problems with thin tapes in normal use

A visual inspection of 205 thin tapes that have been returned from VLBA sites after an observing session shows 9 tapes with tape pack problems, 8 3M and 1 Sony. One of the 3M tapes has spokes as well as an exposed edge. Mounted on a re-cycled NASA self-packing reel, the Sony tape pack is badly scattered, possibly a result of a bad reel: many of the NASA reels were out of specification and warped after years of storage. None of these tapes show up on the log of transferred tapes as having problems with exposed edges during the initial transfer. Problems with transferred tapes are to be discussed in a report to follow.

Several of the new thin tapes have been broken, or have been shortened due to damage caused to the tape when it ran off the end of a reel at high speed. The additional mass of the thin tape reels has uncovered some reel servo problems, and problems with the firmware that drives the reel servos.

Conclusions

At the beginning of Test II, lightning was causing power surges and outages, the software was misoperating to cause on occasion the tape to slew only a few hundred feet before reversing direction, an I/O roller on each of the test drives was sticking, and at least one of the operators was inexperienced with thin tape handling. Unfortunately, the control thick tape was not in use during this period; but the fact that fewer problems have occurred since start up may indicate that the thin tape is more durable than the problems during the first 2 or 3 shuttle tests would indicate.

From the data so far on Sony and 3M, we have no failures which renders a mean time to failure (MTTF) calculation meaningless.

All 6 of the Ampex tapes provided for evaluation have failed, 4 at the AOC and 2 at Haystack. Hans Hinteregger recommends that we not consider Ampex tapes further so that the Ampex data are not included in the MTTF calculation.

A sample of the Sony and 3M tapes have survived Hinteregger's "torture" test to his satisfaction. The edge "melt-down" problems of Test I have not recurred. The remaining problem appears to be the "exposed edge" phenomenum which has appeared repeatedly during

the transfer of thin tape to the new reels and during both Test I and Test II, primarily with 3M tape. Hinteregger recommends that thin tape be operated at lower tension and rewound at a lower speed before shipment to alleviate the difficulty. This change might prevent the edge from shifting initially; but with rare exception, once an edge becomes exposed, no change in speed or tension will recover the problem.

An unsettling part of Test II was the spokes that appeared on 6 tapes during cycle 6 to 9 after the simulated shipping cycle. Three of the tapes were 3M and three Sony. There is no evidence to show that anything changed in the test to cause the spokes. The spokes were only visible after close scrutiny: they may have occurred at other times and were just not detected. For recovery the only action taken was to pass the tape forward and back at 330 ips and 10" vacuum. The vacuum was dropped to 7.5" at about cycle 11 which may have impacted the occurrence of both spokes and edges.

Finally, this writer sees no strong reason to discontinue the procurement of Sony and 3M tape based on Test I or II.

Acknowledgements

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Hans Hinteregger and Alan Rogers of Haystack Observatory provided a significant amount of direction and ideas for the tests.

References:

1. Accelerated Testing, Statistical Models, Test Plans, and Data Analysis, Wayne Nelson, Wiley, 1990.
2. VLBA Acquisition Memo #364, The Accelerated Tape Test, C. Janes, 1993.