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24 November 1998

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Evaluation of Two Triple-Cap Headstack Variants

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17 November 1998

ABSTRACT

Two variants of the VLBI Triple Cap headstack were evaluated as possible improvements to the original triple-cap (OTC) design. One (XTC) allows a manufacturing simplification with no obvious compromises to performance. The other (ETC) required a vacuum of 15”, significantly higher than the standard 10” vacuum, to provide reliable thick-tape-to-head contact. The contouring procedure used with this headstack was not optimal and further tests may be required before a final judgment can be made on its usefulness.

INTRODUCTION

The triple-cap headstack design has proven to be superior to the standard so-called ‘stepped’ headstack in two regards:

1. Allows interchange between thick and thin tape on the Metrum transport with no change in vacuum.
2. Significantly extends the headstack life over the ‘stepped’ headstack design.

Two variants of the original triple cap design were manufactured for testing:

<u>XTC design variant</u>

The XTC design (for eXperimental) differed from OTC only in that the triangular slots between the three caps were modified to rectangular slots, which are easier to manufacture. The width of the 3 ‘lands’ are 100-300-100 um, respectively, identical to the OTC. The XTC was contoured to ~6 mm radius (as received).

<u>ETC design variant</u>

The ETC design (for Equi-TripleCap) has 3 equal 500 um lands separated by two 500 um wide rectangular slots. The initial contour shape was 3 flat lands with outriggers at +/- 3.33 degrees, such that the 6 corners are on an 18 mm radius circle and that each corner is wrapped 1.67 degrees.

ETC has 3 times the contact area of XTC or OTC so that when/if an 'equilibrium' contour shape is reached contact pressure is only 1/3 that of XTC or OTC, given that the total wrap angle, 10 deg, and tension, 10” vac = 2.2 N, are constant.

TESTS

Test Setup

XTC, SP#47260, and ETC, SP#46836, were mounted in one assembly in position #1 and #2 respectively.

A spectrum analyzer was used to measure bandedge read power at 135 or 80 ips for thick and thin tape respectively. SNR was measured relative to the head/electronic noise at 0 ips at 2.2 MHz with 30 kHz RBW. The spectrum analyzer, together with an eye pattern display on a scope, was also be used to assess stability of response.

In addition, PER was periodically spot-checked with a decoder. No attempt was made to minimize PER by identifying/reducing sources of interference, improved grounding, etc.

A single Mk3A head-interface card/cable was plugged, as needed, into the odd or even half of one or the other headstack in the assembly, which used the Haystack acquisition drive as testbed.

Initial XTC Thick Tape Performance

A prerecorded FujiH621 test tape was run at 10” vac 135 ips. All Mk3 heads were tested, the odd heads in reverse as well as forward. SNR ranged from 27 to 30 dB, 3 to 6 dB above spec. There was no significant F/R difference or instability of output. PER was typically 10-5 for all odd heads, only odd heads were checked.

XTC spacing increase at low tension, 5” vac, like typical OTC.

Output was reduced 2 to 3.5 dB when vacuum was reduced from 10 to 5”; this corresponds at the 1500 nm bandedge wavelength to a spacing increase of 56-94 nm. All even heads forward were compared at 5 vs. 10” vacuum. I noted in Mark4 memo #252 similar spacing increase and slight instability at low tension, 5” vacuum, in OTC heads on the Haystack processor, which operate at 10” vacuum regardless of tape thickness.

The average 10”-to-5” loss increased from 2 dB in the outer to 3.5 dB in the inner half of the headstack; significance/cause of this trend is uncertain.

XTC performance unchanged after long 30” vac lap with Fuji H621 tape.

The contour lapping operation, which resulted in irreducible spacing on ETC operating with thick tape, also lapped XTC. As a result, subsequent optical inspection indicated from 3.5 um to about 6.5 um of wear on XTC, decreasing almost monotonically from 6.5 um at Mk3 head #1 to 3.5 um at #15, thereafter constant to #28.

When XTC even heads were retested at 10” vacuum with the same prerecorded H621 test tape, output was not significantly different than before the extended lapping; 11 of 14 heads agreed within +/- 1/2 dB. Further tests at 30 and 5” vacuum showed

a. no difference between 10” and 30” vacuum, and

b. significantly increased spacing at 5” vacuum, with a now accentuated 1 to 5 dB loss trend from low to high numbered heads. The trend is 'consistent' with more wear measured in the outer half of the stack.

ETC contour lapping and thick tape performance

The initial bandedge SNR of ETC ch#2 was 3dB before prolonged 270 ips shuttle lapping at 30" vacuum high tension, with about 50% RH in the tape path. The same 4500' Fuji prerecorded test tape used for XTC was also used throughout for testing ETC thick tape read response.

This same tape was also used as the lapping tape for 9 round trips, about 1/3 of the 210,000' total of lapping required to recover a total of 25 dB of excess bandedge spacing loss, for a good final 28 dB bandedge SNR. At the 33 kfci bandedge wavelength (1500 nm) the 25 dB recovery corresponds at 55 dB per wavelength to the elimination of 680 nm of excess spacing. The remaining lapping footage was applied with an additional 9 round trips of a second 7500' Fuji H621 tape. The first 10 dB was recovered in 45,000' [5rtx4500'], the second 7 dB in 57,000' [3rtx4500' + 2rtx7500'], the third final 8 dB in 108,000' [6rtx7500' + 2rtx4500']. Further lapping [4rtx9000'] at 30" vacuum, with a third 'fresh' Fuji tape, did not further increase response measured at 30 or 15" vacuum at 135 ips. Recovery rate decreases as contact area increases: .22, .12, and .07 dB per 1000' in this case for the 3-session breakdown. The abrasivity of the tape under lapping conditions is also expected to decrease with repeated use, but no attempt has yet been made to quantify this effect.

With ETC contoured at 270 ips with thick tape at 30" vacuum, thick-tape read performance at 10" [but not at 15"] is compromised. Like XTC at 10", ETC at 15" appears to have a slight performance gradient from 27-28 dB for outside to 25-26 dB for inside channels. But at 15" there is no sign of contact instability.

At 10" vacuum there is significant bandedge output loss and instability compared to reading at 15 or 30" vacuum with indistinguishable SNR and stable contact performance. The relative 10" vs. 15" loss gradient across tape width is large, 1.5-3.5 dB for ch#2 to 8-12 dB for ch#28. The 2 and 4 dB range of loss for #2 and #28 respectively indicates spacing instability [actually about 40 Hz amplitude modulation] as observed with the spectrum analyzer. The modulation amplitude increases with frequency or wavenumber and is therefore clearly a spacing, not a mistracking, effect.

An attempt was made to get closer to an equilibrium contour for thick tape at 10" vacuum. This consisted of 3 more 270 ips round trips of the last used 9000' tape at 15" vacuum, instead of at the 30" used in the previous 4 round trips which had left performance unchanged. A much slower and much longer shuttle at 10" or a little less, or the less time-consuming use of true lapping or uncalendered recording tape of equal or slightly greater thickness, would probably produce better results. Nevertheless, some improvement in 10" read performance was noted, with the relative 10" vs. 15" loss dropping to 0.5-1.5 dB for ch#2 and 5-8 dB for ch#28.

Contact pressure on the ETC may be too low to provide reliable contact with thick tape, although such a judgment cannot yet be conclusive. The contour radius achieved by the tape lapping efforts above undoubtedly created a contour with a smaller radius than the equilibrium contour for thick tape operation at 10" vacuum.

ETC with thin Quantegy 741 prerecorded 56 kfci test tape

Bandedge SNR between 17.5 and 20.5 dB was obtained at 80 ips at 10" vacuum with no sign of instability or obvious performance trend across tape width. In theory, assuming no significant additional high frequency loss at 4.5 MHz, this corresponds to a 20.5 to 23.5 dB SNR spread at

160 ips, with 20 dB as the specified worst case. The performance measured is typical of SP heads.

A few channels were also checked at 5” vacuum. Though ch#2 was not compromised at 5”, ch#14 and ch#24 lost 1-5 and 1-7 dB respectively, the latter with 6 dB p/p bandedge amplitude modulation at about 23 Hz. This is equivalent to about 100 nm p/p spacing modulation.

The unstable-at-5” channels were then checked at 7.5” vacuum. They performed at 3/4 operational tension without loss or instability.

<u>XTC with thin tape</u>

Bandedge SNR between 18 and 21.5 dB was measured for the central 28 Mk3A channels at 80ips, with indistinguishable stable performance at 10 and 5” vacuum. XTC has better low tension tolerance for thin than for thick tape.

XTC has better low tension tolerance than ETC regardless of tape thickness. But low tension contour preparation of ETC may improve its operational low tension tolerance.

<u>XTC with thin prerecorded test tape at 160 and 320 ips</u>

The 1 um wavelength SNR of a single channel [#27] was compared at 80, 160, and 320 ips at 5”, 5”, and [5,10,7.5”] respectively for any clear sign of spacing increase or contact instability with speed. None was found, given adequate (10”) vacuum at 320 ips.

SNRs at 2, 4, 8 MHz at 80, 160, 320 ips were 22, 24, and 25.5-20.5 dB respectively. The 160 ips spectrum was stable; the 320 ips spectrum at 5” vacuum was not. The former is consistent within the estimated measurement error to the expected 3 dB increase with a doubling of speed and/or with a typical 'frequency loss' of 1 dB at 4 MHz, and indicates stable contact at 160 ips at 5” vacuum.

At 10” vacuum a stable 320 ips spectrum was obtained with 30 dB SNR at 8 MHz, 8dB higher than the 80 ips 2 MHz value. Ideally, without a change in spacing or high frequency head losses, the 320 ips value should only be 6 dB higher than the 80 ips value. The source of this discrepancy is not clear, but goodness of contact at 320 ips 10” vacuum certainly is! At 320 ips and 7.5” vacuum, only a slight 1 dB instability and 28-29 dB SNR at 8 MHz is evident.

FUTURE TESTING

Profilometer traces of the tape-lapped ETC contour will be analyzed soon. Tests of ETC with further, slightly-flatter-than-equilibrium, contour pre-conditioning should be conducted before concluding that a smaller total contact length is really important.

If so, a total contact length of about 900 um, a compromise between 1500 um for ETC and 500 um for XTC, may be worth evaluating. Contours without, as well as with, slots should also be compared, since the value or necessity of the slots is suspected but not really proven:

1. ETC's lands could be shortened to 300 um to provide a test case with 600-700 um grooves.
2. A slotless XTC/OTC test case could be obtained, that is, a 900 um Wide STepped head, WST, with 6mm contour radius. [This could be converted back to XTC if WST is not an improvement.]

Remember, the primary function of TC heads is to allow reliable mixed operation with thick as well as thin tapes. If thick tapes don't have to be used, the simplest, most reliable, and longest wearing solution is a very wide [1270 um] flat-top such as was tested several years ago.

SUMMARY

The XTC variant of the triple-cap headstack has been shown to be equally competent to the original triple-cap (OTC) headstack design and can be more easily manufactured. The XTC has been placed into service on the Haystack correlator and has so far been trouble free. Judgment cannot be finalized on the ETC design without further testing.

On the basis of these tests, we recommend that all new triple-cap procurements be of the XTC design.