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To: Mark IV Group

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Subject: 280 ips Read-Only Interface, New and Existing Head Usage Recommendations

A new interface was designed to greatly reduce read-crosstalk. It should work as well with new 35-turn Metrum heads at 280 ips as the current interfaces with 48-turn heads at 80 ips. Acceptable 280 ips read performance is also expected with existing 48-turn Metrum heads, though with less margin for reading high-speed recordings by standard SP heads at 160 ips and standard Metrum heads at 320 ips which are degraded by write-crosstalk, compounded in the case of SP by excessive variability and high-frequency rolloff of efficiency.

This memo also contains recommendations for specification of new Mark IV headstacks and for utilization of both old- and new-spec headstacks, particularly and with highest priority for the case of data acquisition at tape speeds to 160 ips (9 Mbps/track) with playback at 280 ips (15.75 Mbps/track). Because recordings at 320 ips are significantly compromised by write-crosstalk, which we have not been able to greatly mitigate, data acquisition at 320 ips should be avoided until the new 280 ips read-only interface is tested and operational in some processor drives.

1.0 When possible, buy and use a 35-turn Metrum triple-cap on processor drives that must perform well at 280 ips read-speed.

1.1 Other things being equal, the reduced-turns head will lower read-crosstalk 6 dB with respect to the standard head.

1.2 In any case, but especially if a standard 48-turn head must be used for 280 ips playback, maximize the resonance frequency of the read-only processor drive interface at about 14 MHz for standard-inductance 48-turn heads:

1.2.1 Use a new low-capacitance high-frequency 1st-stage EF transistor.

1.2.2 Load its base intentionally only with the head. Not with a write-resistor and diodes, as currently implemented for 80/160 ips playback-- which resonates the head at only about 8 MHz and therefore maximizes read-crosstalk at 280 ips. By comparison the Mark 3 read-only interface resonates at about 10.5 MHz, better but still not far enough from the 280 ips bandedge to yield acceptably low read-crosstalk.

1.2.3 Add new small ferrite beads to guarantee preamp stability.

1.2.4 Update the 'Ingalls' filter for stability.

1.2.5 Do not use the series diodes required in the Mk4 field read-or-write interface configuration.

Avoid 2-3 dB noise penalty.

Note: These new high-speed read/crosstalk head and interface design considerations, and experiments

conducted through August 2000 are reviewed in memo #285, which follows my working notes appended regularly to Haystack-internal minutes of recorder group meetings.

1.3 A worn Metrum headstack with about 12 microns remaining depth of gap will be more efficient and provide at least 3 dB more SNR than a new one with more than 25 micron minimum initial specified depth of gap. We have never worn out a triple-cap on a processor drive operating with a dry-air kit that guarantees less than 20% RH in the tape path. Since we can now be sure that low depth-of-gap triple-caps will not wear out prematurely in the specified low-humidity tape-path environment,

I recommend ordering new 35-turn Metrum triple-caps for processor head-replacement with an initial depth of gap in the range 12-15 microns. The high efficiency due to lower depth-of-gap more than compensates for the reduction of turns from 48 to 35.

More importantly for reading at 280 ips, the lower depth-of-gap also reduces the rolloff of read-efficiency with frequency.

1.4 SP heads, with or without reduced turns and/or depth-of-gap, are NOT recommended for 280 ips playback:

SP head-efficiency was found typically to drop rapidly with frequency so that best SNR and digital read performance is obtained at 80 ips where read performance is as good or perhaps even slightly better than comparably configured and worn Metrum heads.

But the SP heads typically show no increase in SNR at 160 ips while Metrum heads show the full expected 3 dB increase.

At 320 ips even low-depth-of-gap SP heads are typically -2 dB at bandedge with respect to 80 ips, while similar Metrum heads are typically +5 dB with respect to 80 ips, within 1 dB of the 6 dB expectation without any frequency-dependent loss.

2.0 For data acquisition:

2.1 Use existing standard Metrum or SP heads for 80 and 160 ips write-speed.

2.2 Set write voltage carefully to minimize worst case channel error rate in 80 ips mode C test recordings.

2.2.1 Good compromise for all channels is hard to find for SP heads and their 80 ips write performance is typically inferior to Metrum at 80 ips and their own 160 ips write performance. The best write-voltage selected at 80 ips should be also be used for writing at 160 ips; a separate 160 ips optimization is not needed and is discouraged because the 80 ips determination is more critical and can't be improved upon in practice.

2.2.2 Best SP digital write performance was surprisingly found to be typically associated with 1 to 2 dB underdriven bandedge response.

2.2.3 With Metrum heads, all experience teaches that the optimum write-voltage should be just high enough to maximize bandedge output in order to minimize error rate. Even a little overdrive, evidenced say by a 1/2 dB reduction in bandedge output, typically causes error rate to increase 1 - 2 orders of magnitude. This is due to non-linear intersymbol interference in the write-process.

Typically error rate increases only slowly with 1 to 2 dB of underdrive when write-crosstalk is not significant, but underdrive increases write-crosstalk susceptibility in a simple heuristic model.

2.3 Adequate write and write-crosstalk performance at 320 ips has been demonstrated so far only on standard Metrum stepped and triple-cap heads using 1000-ohm write-only and read-or-write interfaces. At 320 ips a half-inductance 35-turn SP experimental triple-cap with low 12-micron depth of gaps also performed well, but not better than the standard Metrum head -- and only with the write-only interface: Several channels failed the $PER < 6 \times 10^{-4}$ spec with the read-or-write interface. Memo #286 details the write testing and comparison of this experimental SP and two standard Metrum heads with these Mk4 write-only and read-or-write interfaces. Write digital performance and crosstalk at 80, 160, and 320 ips write-speed has been measured and compared so far only at 80 ips read-speed, in every case using Westford's Metrum triple-cap with its 1000-ohm read-or-write interface for reading. Reading at 160 ips should yield comparable results but remains to be tried to be sure. A new prototype read-only head/interface/equalizer 280-ips read-channel needs to be completed and tested to see if the combined effects of 320ips-write and 280ips-read crosstalk have been sufficiently mitigated.

More important is first to confirm robust 280 ips read performance for 80 and 160 ips field recordings made with both existing Metrum and SP heads.

The new headstack specifications proposed in memo #288 should not only guarantee robust 280 ips playback but indirectly assure nearly write-crosstalk-free 320 ips recording. This expectation for new-spec Metrum heads awaits write-testing upon receipt of first items just ordered.

Discussion

These recommendations are based on extensive efforts at Haystack in the last 1.5 years to characterize and improve especially traditionally-unspecified write performance and both write- and read-crosstalk performance of VLBI headstacks.

Considerations include written-in intersymbol interference, to which SP heads are now known to be more prone -- due to a steeper rolloff of head efficiency with frequency and to greater head-to-head variations in efficiency, hence in 'optimum' drive voltage for different heads within a headstack.

Adjacent-channel interference, both written-in and as-read at high speed, at 320 and 280 ips write and read target speeds respectively, was found to be a significant problem. Adjacent-channel interference increases with write and read data rate.

The former, write-crosstalk, is the result of non-linear processes like writing itself -- and is still not well understood theoretically though substantial efforts to characterize it were made late in 2000. A detailed report will be found in memo #286. This second study, showed pretty good $PER \sim 10^{-4}$ 320-ips write-performance with a 'worn' standard Metrum stepped and a relatively unworn standard Metrum triple-cap headstack using a 1000-ohm write-resistor write-only interface and a 1000-ohm read-or-write interface respectively. Nevertheless 320 ips write performance was definitely degraded by a factor of 5 to 10 compared to writing at 160 or 80 ips. Note also that typically fielded Mk4 recorders have 1500-ohm write-only and 2000-ohm read-or-write interfaces with still untested relative effects on write and write-crosstalk performance. In my study (so far) analog and digital performance was measured only at 80 ips read-speed however where read-crosstalk is a negligible contributor to overall performance.