VLBA ACQUISITION MEMO #149

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To: VLBA Data Recording Group

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Subject: Model for recorder tracking response to tape slitting signatures

Introduction

Since the edge guiding action of a recorder is not instantaneous and the heads are not directly over the edge guiding point, it is important to have a model which will predict both the short term A.C. and long term D.C. tracking interchange signatures between machines in different configurations, heads in different locations and different tape directions. It is now thought that most of the A.C. signatures due to tape slitting errors - in particular, the quasi periodic "weaving" produced by the rotating slitting blades - see Memo #135. Long term D.C. tracking interchange has been extensively discussed in previous memos. This note will concentrate on the A.C. component due to geometric irregularities.

Mathematical Model

Let x be the distance down the tape and $y(x)$ be the distance of one edge (the one providing guidance) from a perfectly straight reference line. Now let $t(x)$ be the path the tape actually takes as it passes over the first roller (the capstan in the present configuration, the idler in the new proposed configuration). With no bending of the tape it will be drawn over the roller in straight line without regard to edge irregularities. With bending, the linear scale of the tape is altered so that one edge will have a larger linear (footage) rate than the other. The compressed edge will have the larger footage rate. The scale difference between edges of the tape due to elastic bending is

$$W/R$$

where W = tape width

R = radius of curvature

The differential tape speed (in units of the original tape dimensions before elastic deformation) produces a change in the angle of the reference line ϕ with distance as the tape is drawn over the roller such that

$$\frac{d\phi}{dx} = \frac{1}{R}$$

Now, since the tape is drawn straight across the roller

$$\frac{d\,t}{d\,x} = -\phi$$

and hence

$$\frac{d\,2\,t}{d\,x^2} = \frac{-d\,\phi}{d\,x} = \frac{-1}{R}$$

From bending beam theory (solving polynomial) the radius of curvature of the tape at the roller is given by

$$\frac{1}{R} = 3\Delta/L^2$$

where Δ = beam deflection = $y(x+L)-t(x)$

L = distance from roller to edge guide

and hence the tape will obey the following linear homogenous differential equation

$$\frac{d^2\,t}{d\,x^2} = (3/L^2)\,\big(t(x)-y(x+L)\big)$$

whose unit step response is

$$t = 1-e^{-\sqrt{3}\,x/L}$$

and transfer function

$$1/(1-S^2L^23)$$

The tape tracks the edge irregularities with a 1/e response distance of $L/\sqrt{3}$. Figure 1 shows the response to a step edge irregularity at x = 0. Since the step reaches the edge guiding region before it reaches the roller, the tape starts to move along the roller axis before the step arrives at the roller. In a system with more rollers the response is more complicated and is more clearly represented by an equivalent circuit analogy. The filter function for the tracking response on the capstan (when preceded by an idler) is more complex since the curvature of the tape depends on both the beam deflection and slope owing to an additional constraint which imposes continuity of slope across the idler/roller. Again, solving the beam polynomials and forming a differential equation

$$\frac{d^2\,t}{dx^2} = 6/L^2\,\left(t\,(x) - y\,(x + L) + \left(\frac{L}{3}\right)\frac{dy\,(x+L)}{dx}\right)$$

where

t = tracking at capstan - relative to the idler

L = distance between idler and capstan

which has a step function response

$$t = 1 - (2/3)e^{-\sqrt{6}\,x/L}$$

and transfer function

$$(1 - SL/3)/(1-S^2L^2/6)$$

Figure 2 shows an equivalent filter for the tracking response. The tracking at the headstack is approximated by a weighted combination of the response at the idler and capstan. Without idler the tracking at the headstack can be approximated as a weighted combination of the response at the capstan and the input function.

The same equivalent filter can be used to model dynamic skew from the first derivative of the tracking and tension noise from the second derivative. Figure 2 also shows the equivalent filter for the recorder configuration with a fixed post in place of an idler.

Figure 3 shows the tracking response to sinusoidal edge signatures. At long wavelengths the tape follows the edge signature for all headstack locations. In the short wavelength limit the rollers low pass filter edge noise so that the response at the headstack is zero except in the fixed post configuration. The difference in tracking response between upper and lower headstack locations and between machines in different configurations peaks at a wavelength of about 10 inches which is unfortunate since many tapes have a large slitting signature at this wavelength. However, the worst amplitude is only about 20% of the signature amplitude. Also shown in Figure 2 is the tension noise produced by bending as a fraction of the tension produced in the vacuum column.

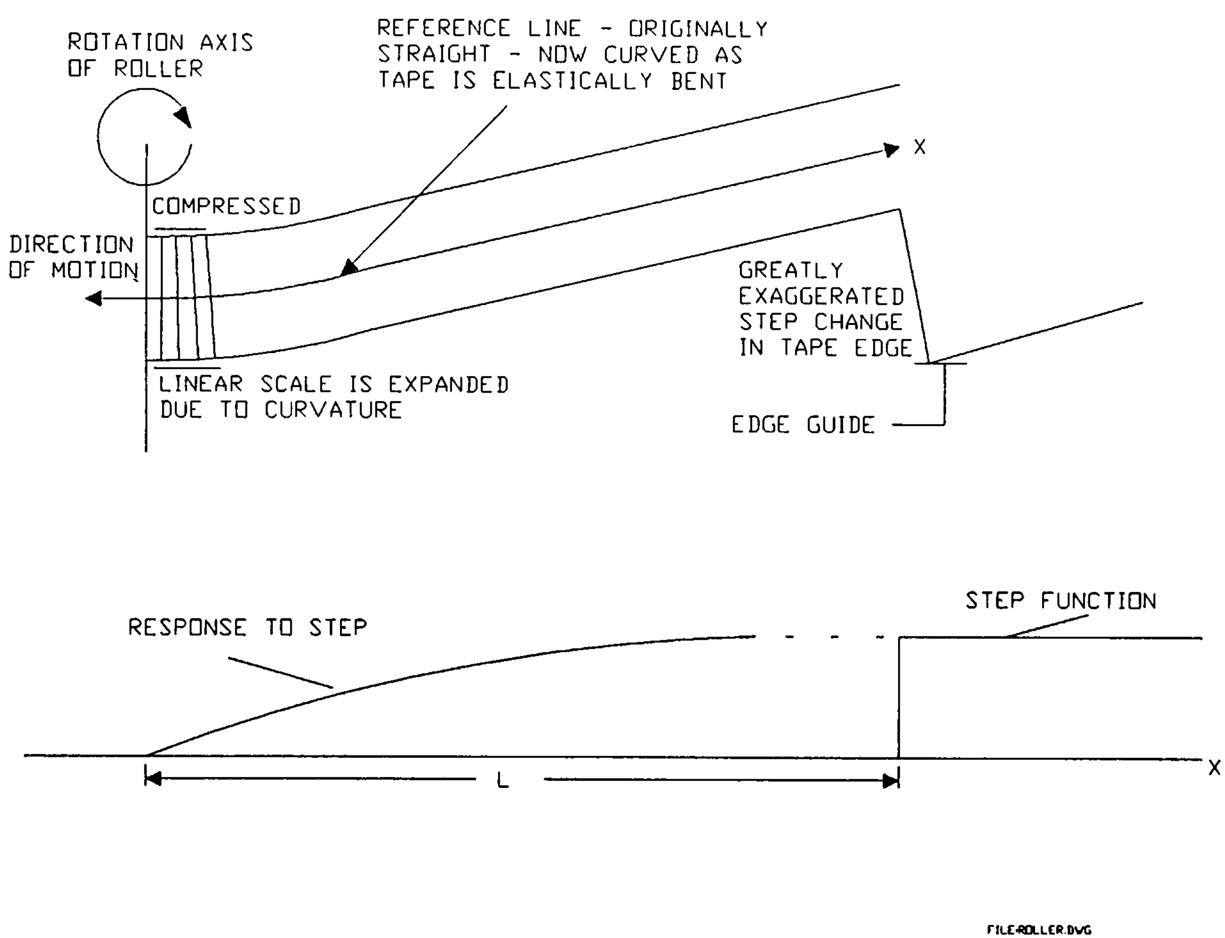

FIG 1 TRACKING RESPONSE TO STEP IN TAPE EDGE

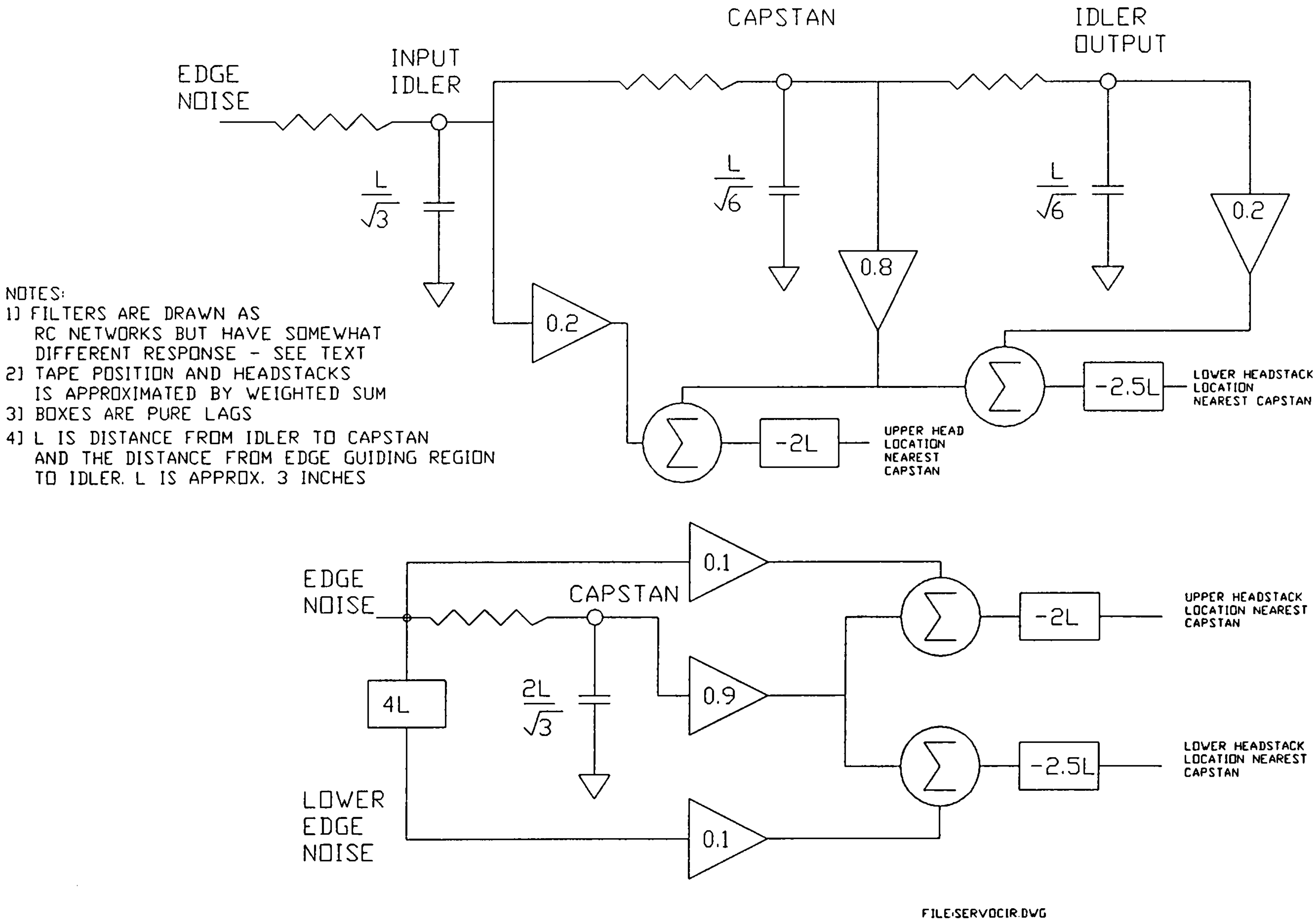

FIG 2 EQUIVALENT CIRCUIT OF MECHANICAL EDGE GUIDING

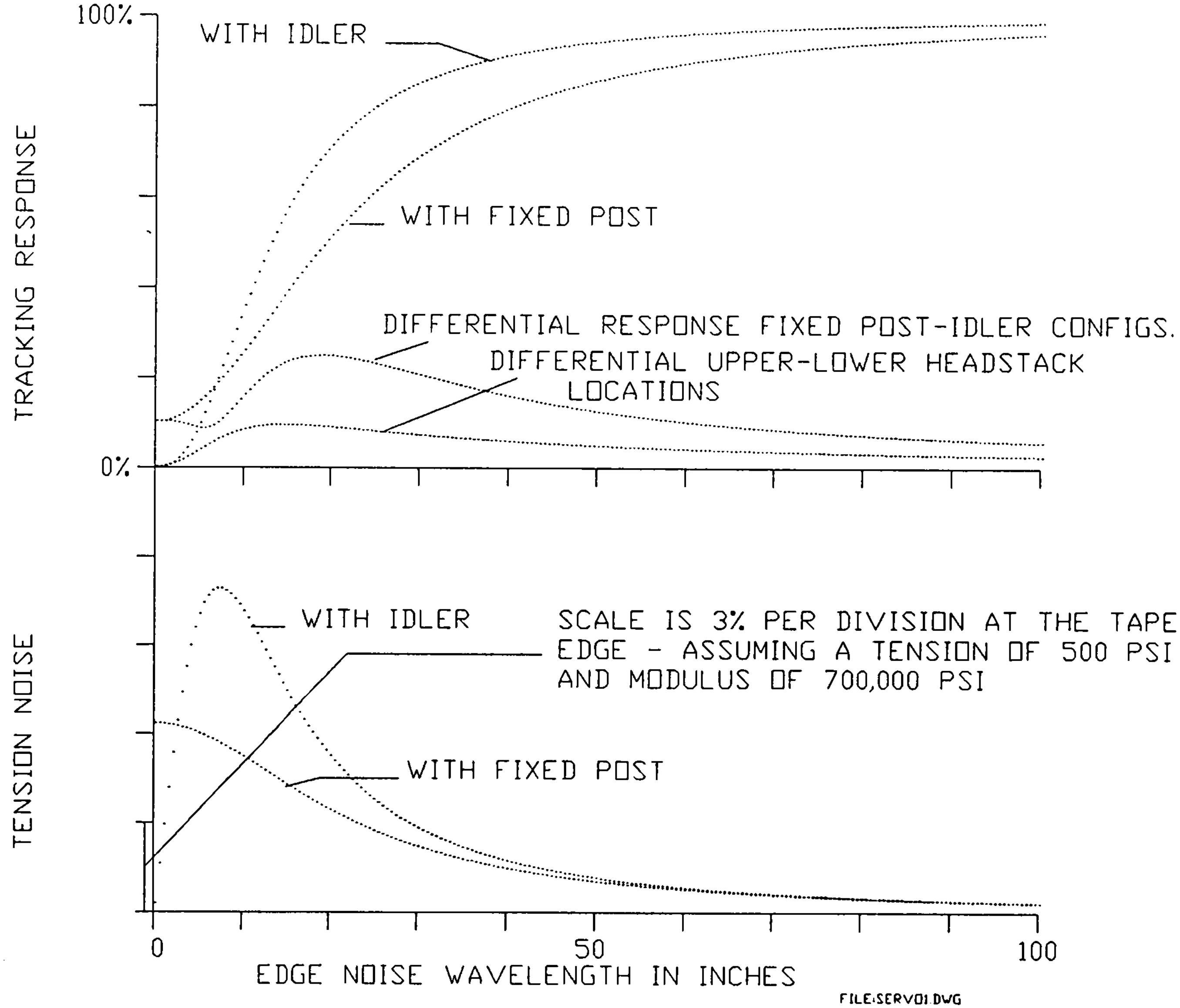

FIG 3 TRACKING RESPONSE AND TENSION NOISE FROM TAPE SLITTING ERRORS