Effective Permeability and Imaging of Multilayered Soft Films for Perpendicular Recording Media

"Reflections on Imaging… "

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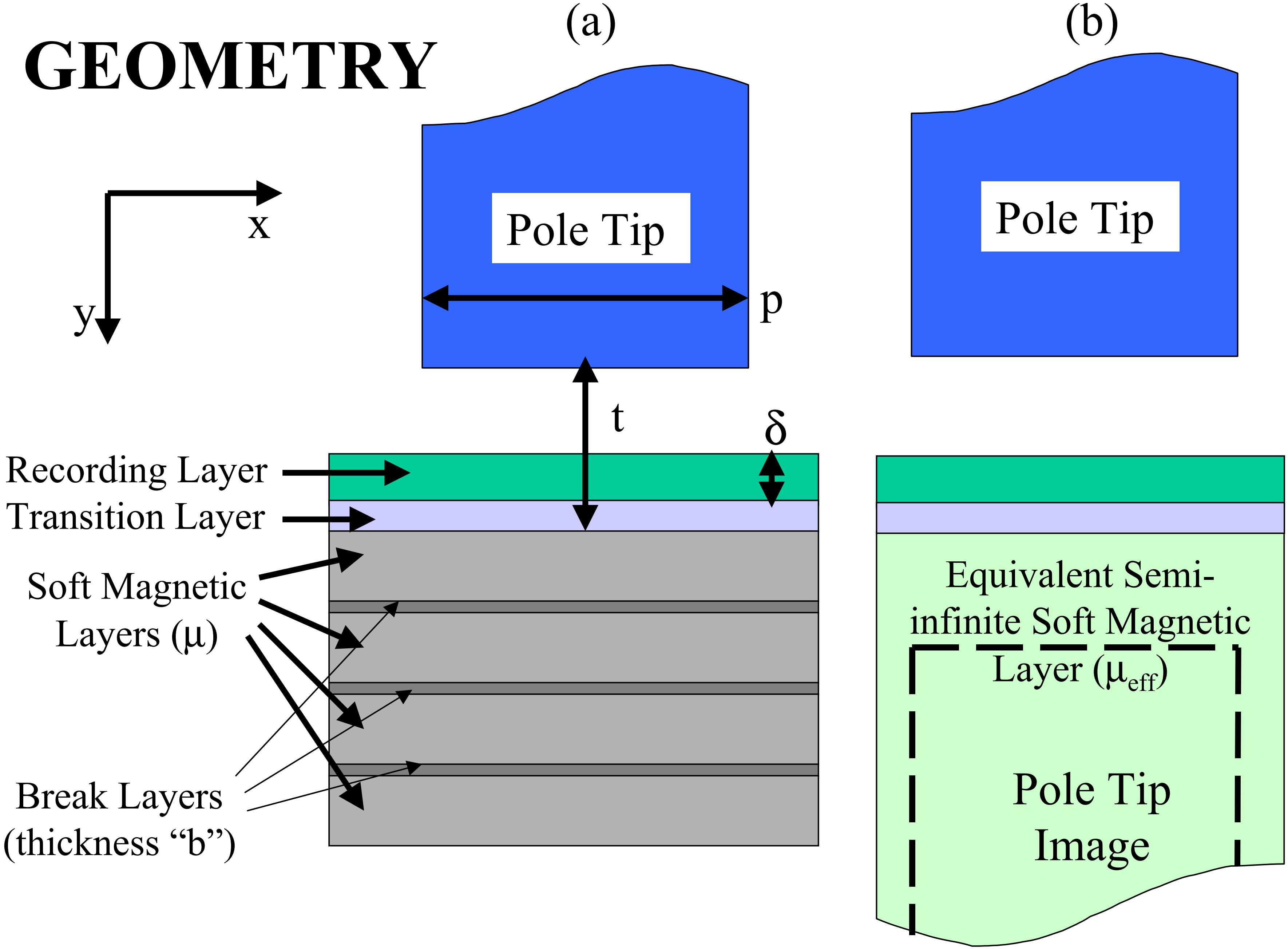
GEOMETRY

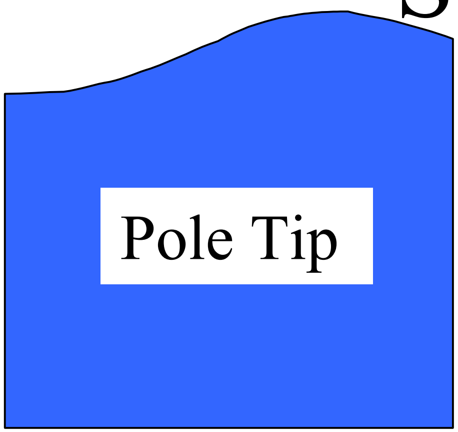


(a)
(b)
x
y
Pole Tip
p
t
δ
Recording Layer
Transition Layer
Soft Magnetic Layers (μ)
Break Layers (thickness "b")
Pole Tip
Equivalent Semi-infinite Soft Magnetic Layer (μ_{eff})
Pole Tip Image

DEFINITIONS

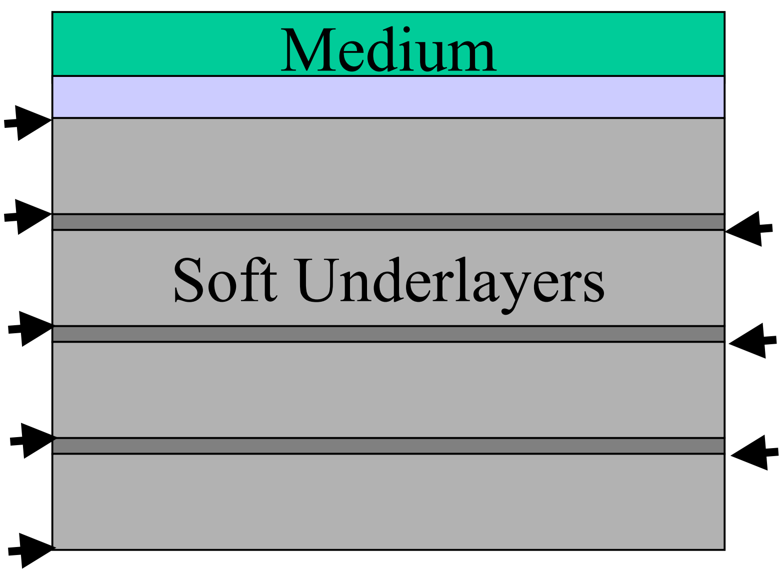
- Effective Permeability: Permeability of a semi-infinite soft magnetic layer having the same imaging effect as the multilayered structure at a given wave number
- That is, $\mu_{eff} = \mu_{eff}(k)$, varies with wave number

ANALYSIS OF MULTILAYERED STRUCTURE (1)



$$V_i(k,y) = v_i^+(k)e^{ky} + v_i^-(k)e^{-ky}$$

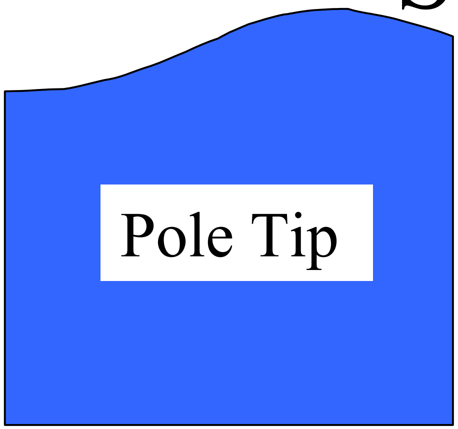
Apply boundary conditions at each interface y_i (see arrows)

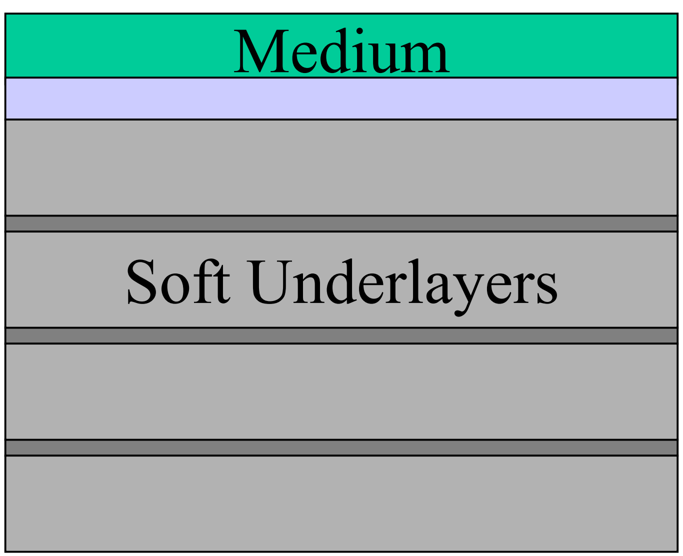


$$\begin{pmatrix} v_i^+ \\ v_i^- \end{pmatrix} = \frac{1}{2} \begin{bmatrix} 1+\dfrac{\mu_{i+1}}{\mu_i} & e^{-2ky_i}\left(1-\dfrac{\mu_{i+1}}{\mu_i}\right) \\ e^{2ky_i}\left(1-\dfrac{\mu_{i+1}}{\mu_i}\right) & 1+\dfrac{\mu_{i+1}}{\mu_i} \end{bmatrix} \begin{pmatrix} v_{i+1}^+ \\ v_{i+1}^- \end{pmatrix}$$

$$v_i = R_i v_{i+1}$$

ANALYSIS OF MULTILAYERED STRUCTURE (2)





$$v_{N+1} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

$$v_1 = \prod_1^N R_i \begin{pmatrix} 0 \\ 1 \end{pmatrix}$$

N = number of interfaces

μ_{eff} is determined from v_1

$$U = \frac{-v_1^+ e^{2kt}}{v_1^-}$$

$$\mu_{eff} = \frac{1+U}{1-U}$$

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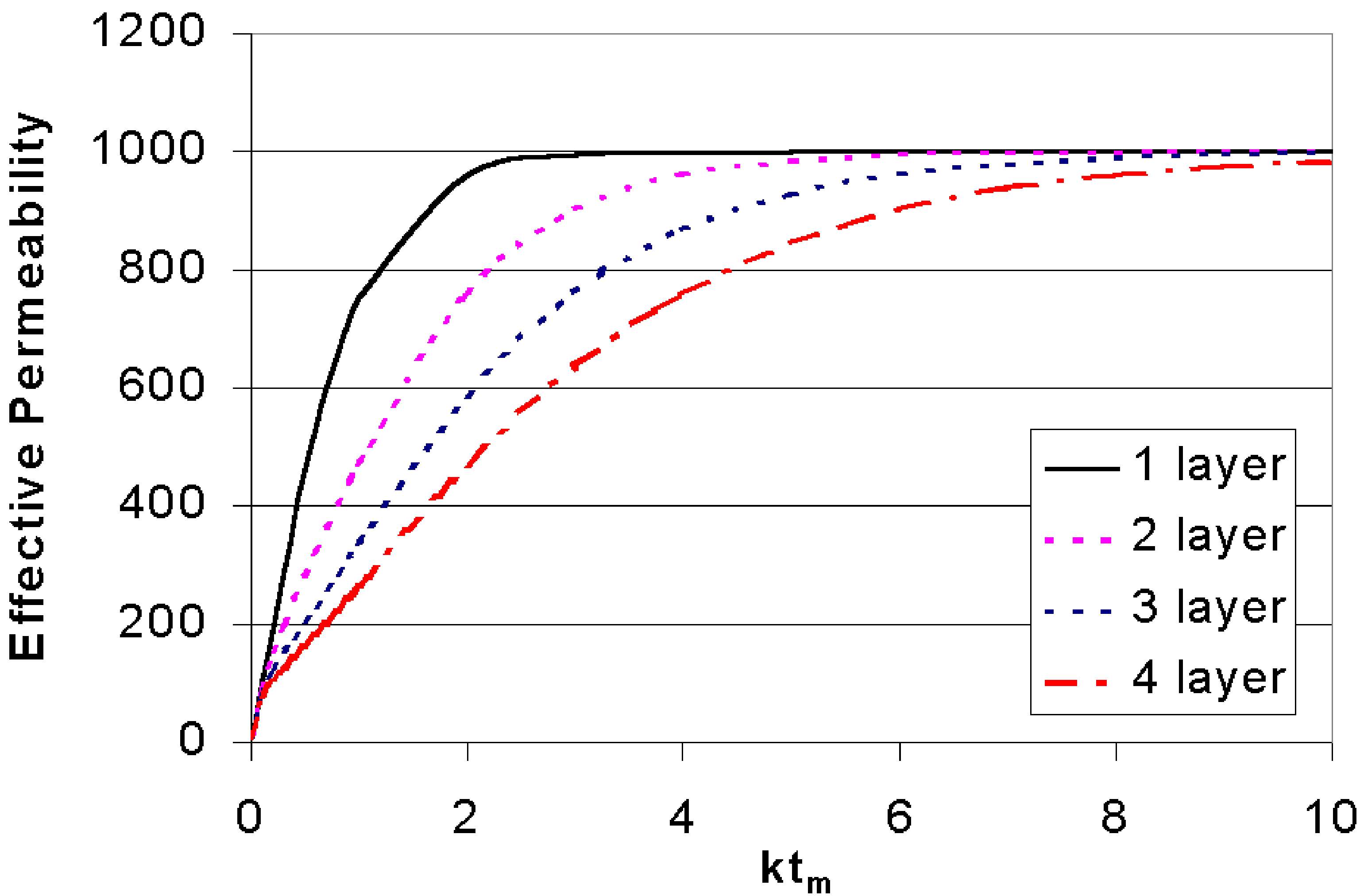
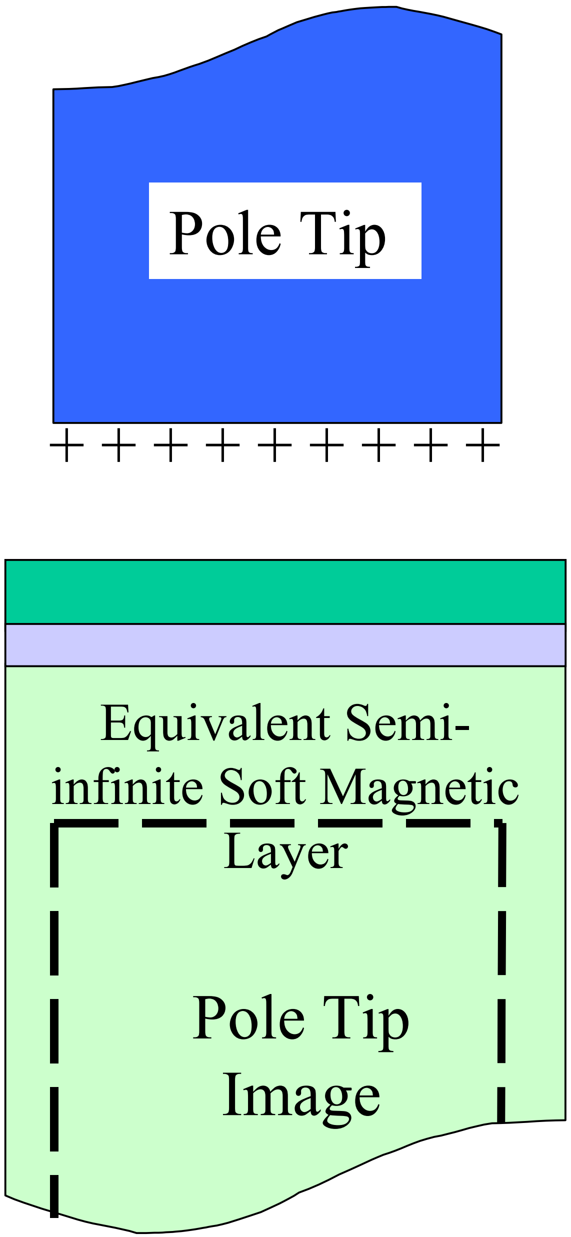


Effective permeability vs. product of wave number times total thickness t_m of soft magnetic composite underlayers. The total thickness of soft magnetic material is 80nm. Soft layers are separated a break layer of 3nm. kt_m of 10 corresponds to 1000 kfci for this case.

SIMPLE KARLQVIST-LIKE PERPENDICULAR HEAD FIELD



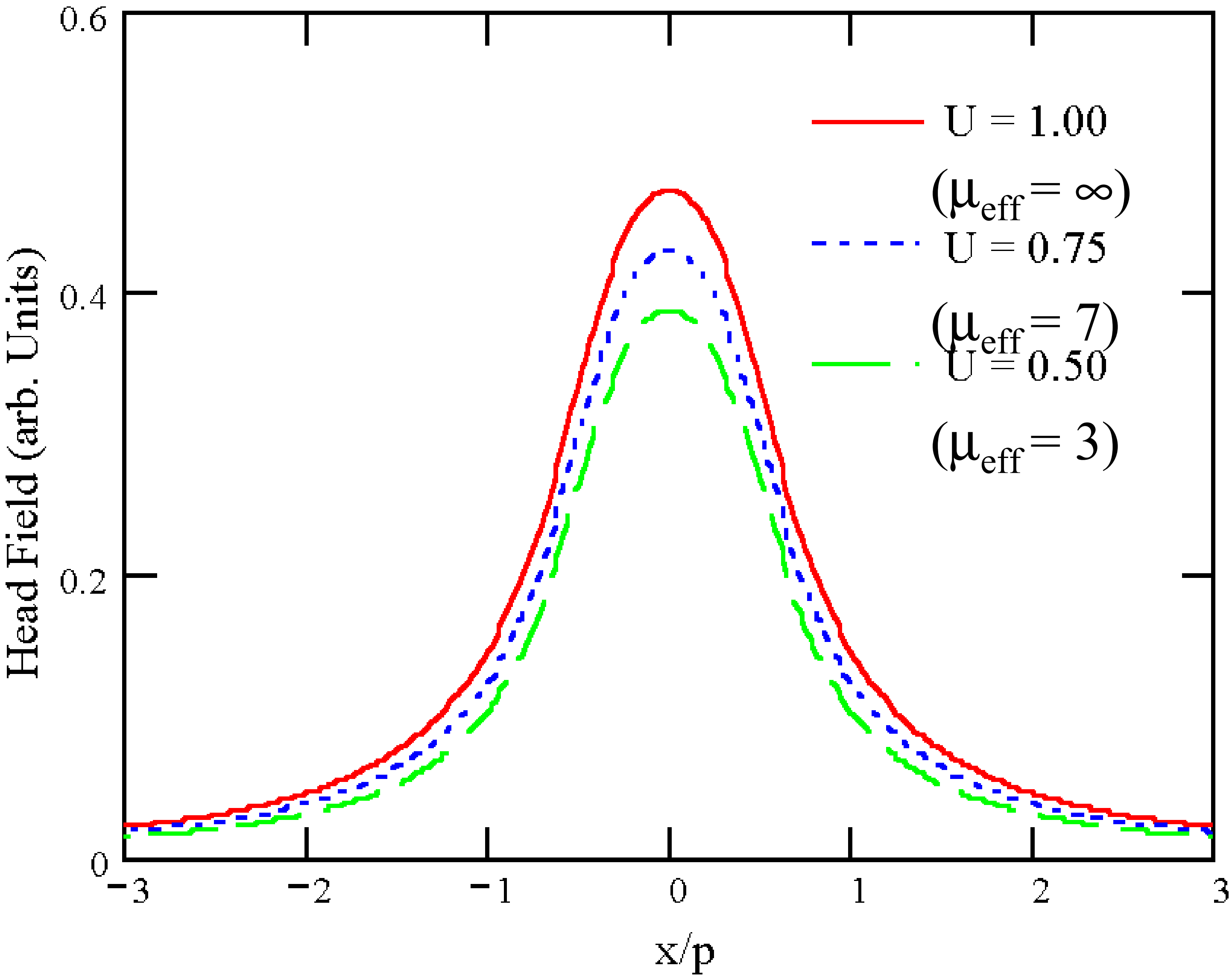
Assuming uniform charge density:

$$H_y(h) = \frac{1}{2\pi}\left[a\tan\left(\frac{x - p/2}{t+y}\right) - a\tan\left(\frac{x + p/2}{t+y}\right)\right]$$

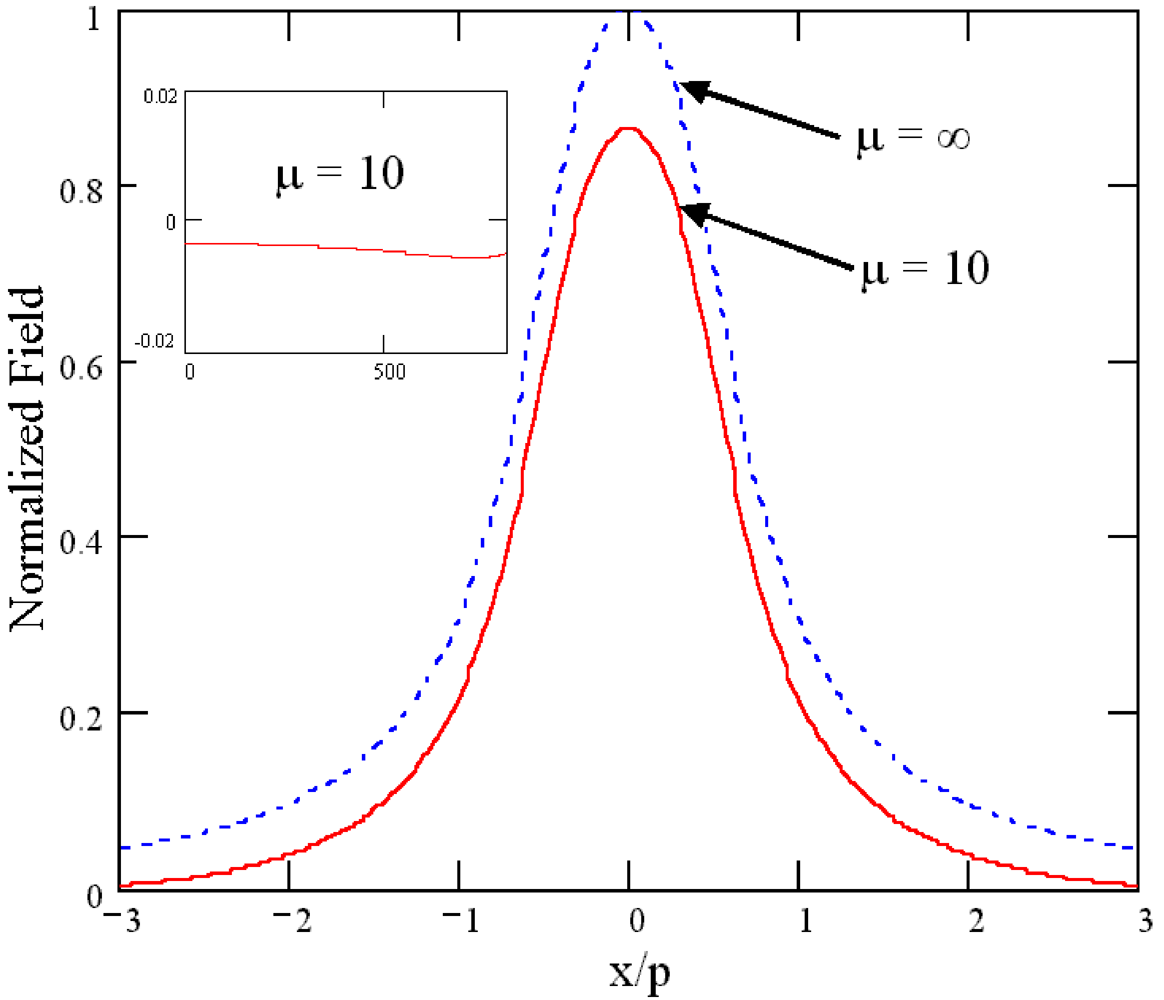
Imaged Karlqvist field:

$$H_y(i) = \frac{1}{2\pi}\left[a\tan\left(\frac{x - p/2}{t-y}\right) - a\tan\left(\frac{x + p/2}{t-y}\right)\right]$$

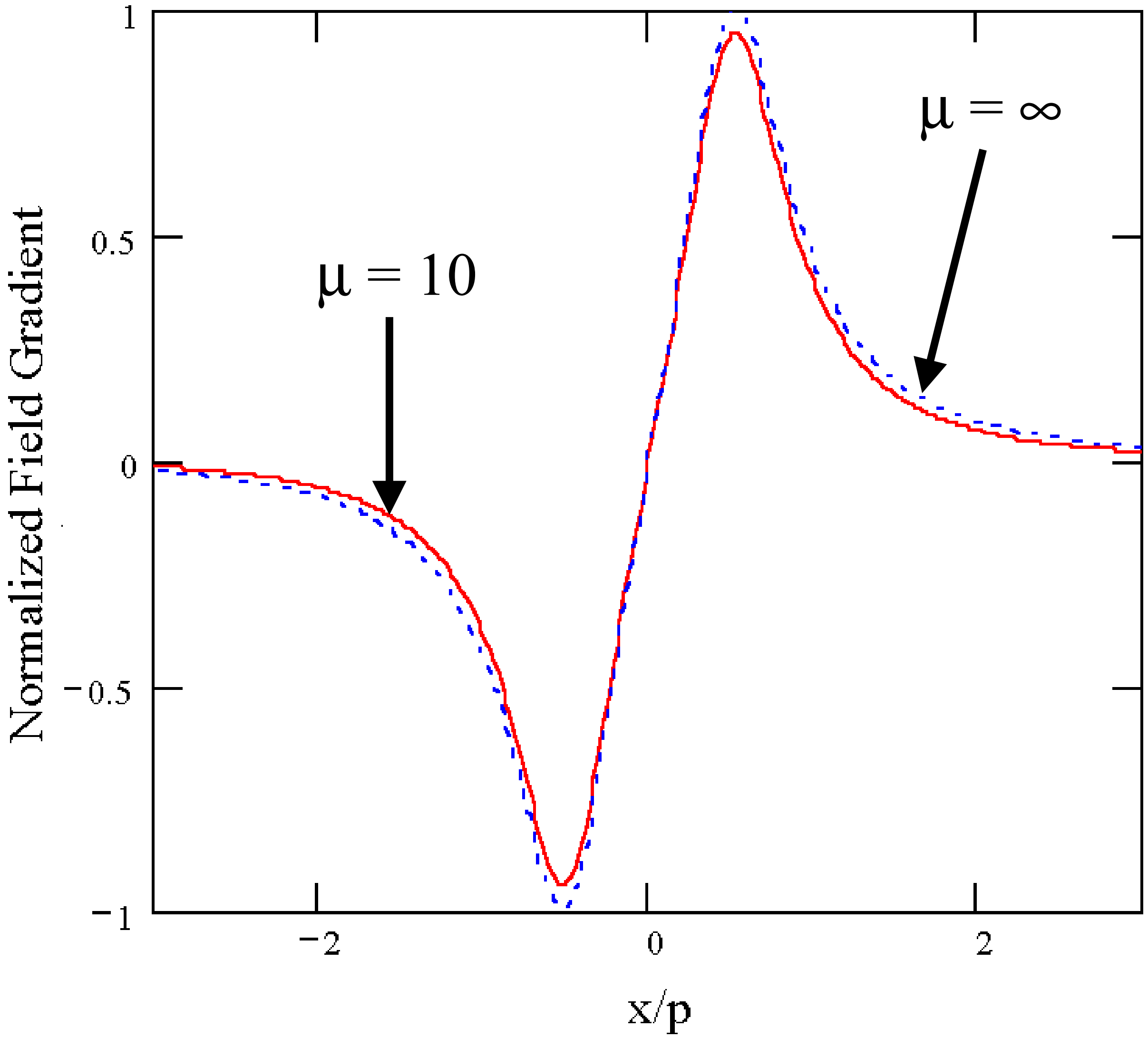
$$H_y(total) = H_y(h) - U \cdot H_y(i)$$



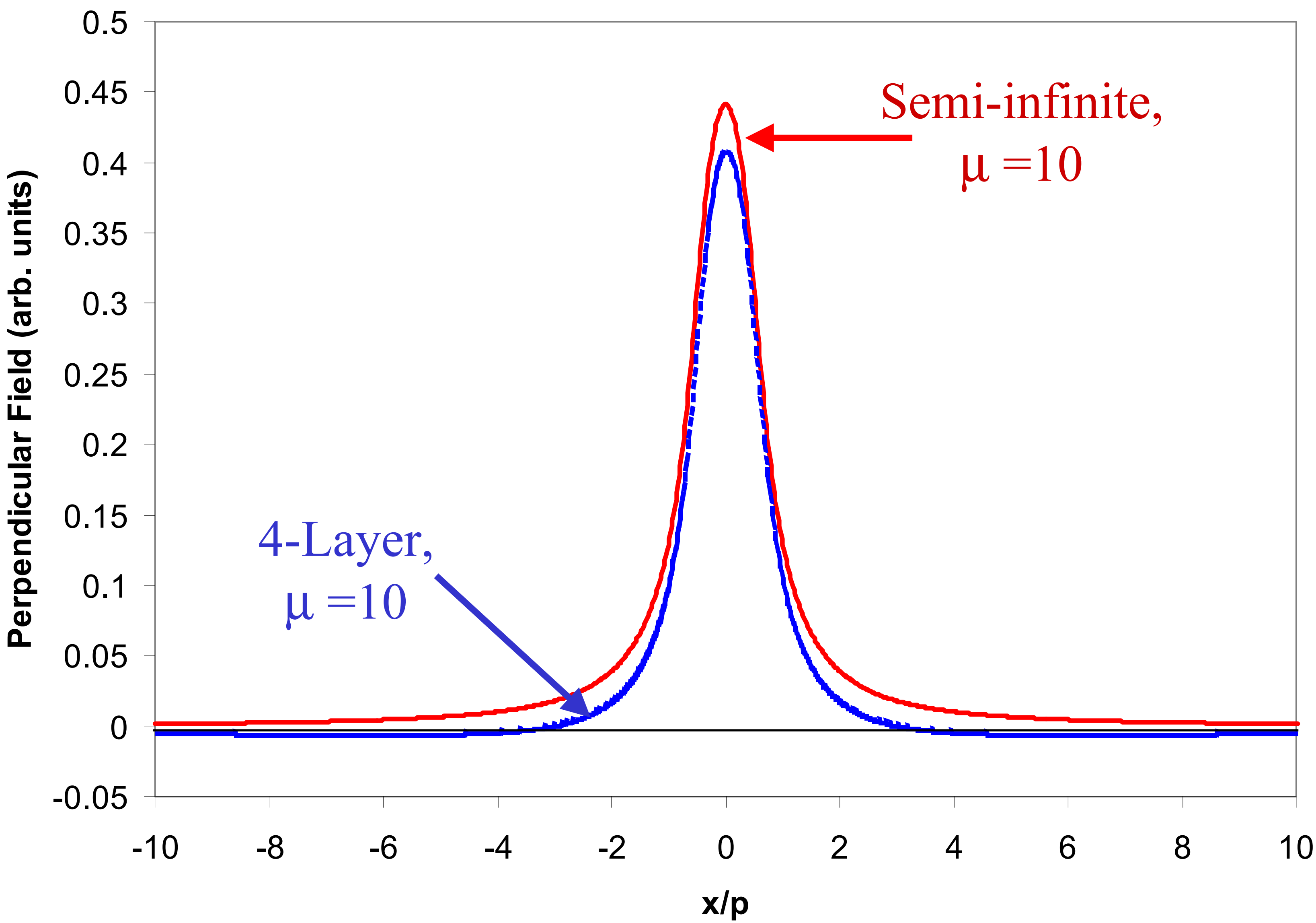
Semi-infinite soft underlayer: total perpendicular head field vs. normalized distance down track x/p for imaging (reflection) factors 1.00, 0.75, and 0.50



Normalized perpendicular head field for 4-layer back layer for μ = ∞ and μ = 10 vs. distance down-track. Total thickness of back layer magnetic material is equal to pole-tip width. Negative field tail of field for finite permeability (shown in insert) is caused by the fact that the dc component of the field has zero contribution from the image.



Field Gradients for head fields shown in prior figure. Despite differences in the field plots the gradients are almost equivalent.



Comparison of perpendicular field with μ =10 for semi-infinite soft magnetic back-layer and 4-layer case

COMMENTS AND CONCLUSIONS

- μ_{eff} approach is simple and useful for studying multilayered soft structures
- write fields with multilayers exhibit negative tails because of zero μ_{eff} at DC
- full imaging at high wave numbers maintains the field gradient
- important to maintain high bulk permeability in films to avoid writing degradation
- this approach can be extended to anisotropic films and 3D modeling