IMPULSE SHIELDING OF SOLID COAX LINES

Considered in the time domain, shielding of magnetic fields is analogous to low-pass filtering in that the rise and fall times of pulses are drastically reduced by good shields. Amplitude, time, size, structure and material properties are critical parameters affecting such reduction. To illustrate, the two nomographs of this brief article contain all information necessary to quickly calculate the reduction of sharp pulses in a typical situation often encountered in practice.

If a rectangular current pulse of peak value *Ip* and duration *T* travels along the outside of a solid coaxial line, the inner conductor will carry a corresponding impulse current rising linearly to a peak value *Ic* at the end of *T*, and decaying slowly thereafter. In the case of multiple inner conductors, common mode pulses are generated. In this context, we consider any pulse having a rise time 2N (17dB) times greater than the rise time an infinitely steep pulse would create on the inner conductor.

Two cases have to be distinguished:

1. **The nonmagnetic case**: As Figure 2 shows, the ratio if *Ip*/*Ic* (in Nepers) changes very rapidly as a function of *T* of the pulse and thickness *d* of the shell. See the example given in the nomograph.
2. **The magnetic case**: It is more complex, but, quite manageable with the double-nomograph of Figure 3. Two conditions, having clearly different consequences, are involved:
   (a) If $T = tp$ (protection time), a minimum attenuation occurs (for *tp*, the shield is just saturated throughout). For *T* smaller than *tp*, the attenuation becomes $a_{min} \times (T/tp)$.
   (b) For *T* much larger than *tp*, the attenuation is determined by the conductivity of the coax shell using Figure 2.

Examples:

A. What is the protection time *tp* and the minimum attenuation a_{min} for a sharp pulse of Ip = 10,000 A on a workhardened Supermalloy coax having d = 0.5mm thickness and $ro = 1$ cm ? Answer: tp = 5µs and a_{min} = 6.3N

B. What pulse width *T* cannot be exceeded if the induced inner current should be much smaller (let's say -10N) than the outer causing current *Ip*? Answer: 20n sec.

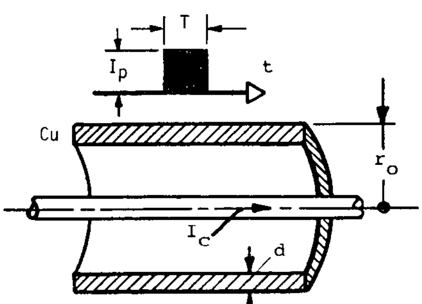

FIGURE 1:

The nomographs are invalid for outer conductors having holes which drastically change the transfer impedance. Figure 1 is based on equation 28 of the paper, "*Pulse Shielding by Nonferromagnetic and Ferromagnetic Materials*" by F. J. Young, Proc. IEEE, April, 1973.

Assumption for nomograph in Figure 2:

1. The coaxial line is made of solid copper tubes with no holes or slots in the outer tube.
2. The radius of the outer tube is many times larger than its thickness.
3. For a rectangular pulse of amplitude *Ip* and width *T* on the outer tube, a maximum current of *Ic* is present on the inner conductor.
4. If the tubes are not made of copper *d* must be multiplied by σ.

$$\sigma = \sqrt{\sigma_{cv}/\sigma_m}$$

where σ_m is the different material. For example:

σ_m	material.
1.28	Aluminum
2.0	Brass
3.6	Lead
6.5	Stainless Steel

Notes for nomograph in Figure 3

The double nomograph is designed for 80% Ni-Fe alloy (supermalloy) having the following properties:

$Bs = 0.75$ Wb/cm^2

$\sigma = 1.6 \times 10^6$ (ohm-m)$^{-1}$

$Hc = 0.01$ Oe (annealed)

$Hc = 0.4$ Oe (work hardened)

For other than supermalloy material, use multipliers according to the following design formulas:

$$e^{a_{min}} = Ip/2\pi r_o H_c$$

$$t_p = \pi r_o d^2 \sigma B_s / I_p$$

For instance, for 41% Ni-Fe alloy having a $Bs = 1.54$ Wb/m^2, multiply *tp* by 2.

Minimum attenuation (a_{min}) occurs if *d* is such that the shell is just saturated throughout. This is when pulse width *T* is equal to protective time *tp*.

If *T* is many times greater than *tp*, the attenuation is only determined by the material property, that is, the conductivity.

The nomographs of this article are taken from Dr. Schlicke's book, "Electromagnetic Compossibility."

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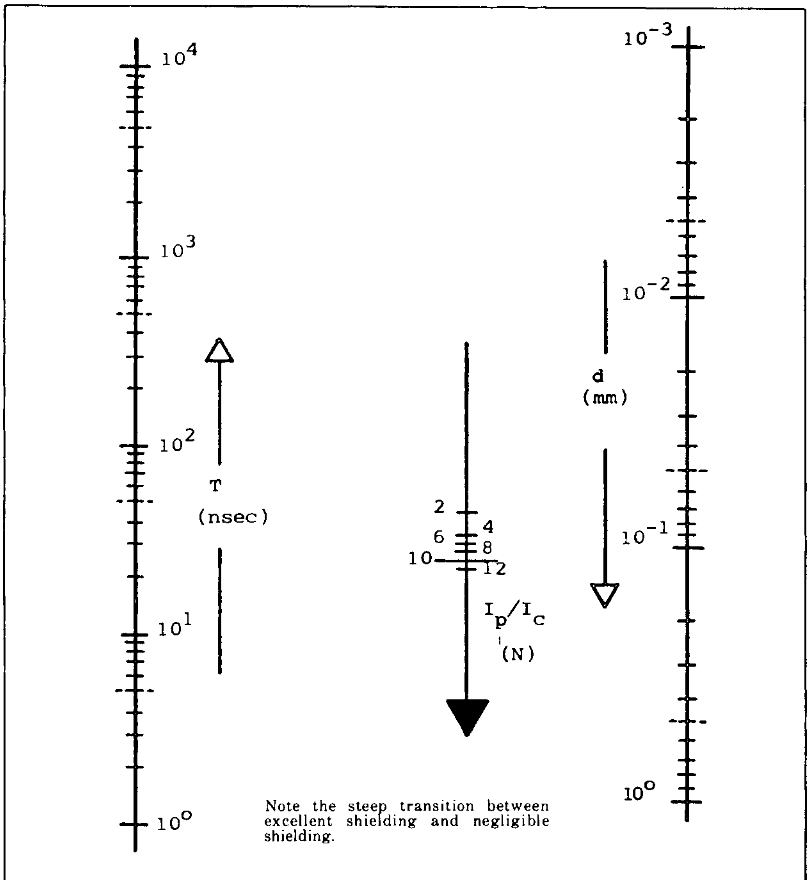

FIGURE 2. IMPULSE SHEILDING OF COAX. LINES: NON-MAGNETC CASE

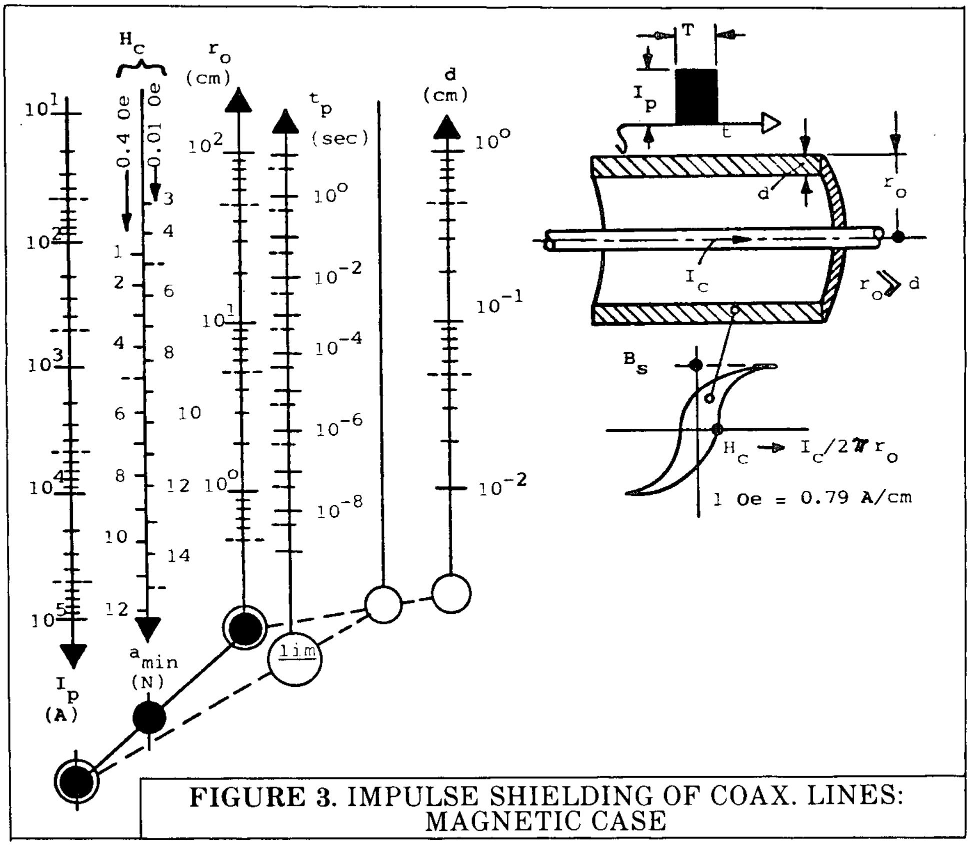

FIGURE 3. IMPULSE SHIELDING OF COAX. LINES: MAGNETIC CASE