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DIFFUSE DISPERSIVE DELAY and the TIME CONVOLUTION / ATTENUATION of TRANSIENTS *

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Introduction:

The Fourier analysis of transients often neglects the phase-delay characteristics and unfortunately if the phase-delay data is retained the computer data shows only the phase angle and looses the real 2pi+, time-delay parameters.Lossy, conductive materials all have a time delay that are (equ 1.2) sq-rt functions of the conductivity, permeability and the inverse of frequency which "spreads-out" the time of arrival of transients propagating through the material to the extent that "CW" **measurements of shielding effectiveness are not - by themselves - a true evaluation of transient protection.** Test data and analytic evaluations are presented to show (claim!) that relatively poor 100 Khz shielding of 12 Db can "effectively" provide an EMP transient reduction of 100 Db. and more-importantly demonstrates several techniques for lightning-surge attenuation as an alternative (or addition) to "crow-bar", spark-gap or power-zener type clipping which simply reflects the surge.

A time-delay test method is shown which allows CW testing - with a convolution program to define a "Transient Shielding Effectivity" where the Fourier phase characteristics of the transient are known or can be broadly estimated.

CONCLUSIONS

Even very thin shields significantly alter the wave-form of transients due to phase-delay,**not attenuation** - which is very small at LF (<.1 Mhz).

Shielding effectiveness - for transients - cannot be evaluated simply by a convolution of the CW measurements techniques. This is an error of magnitude - usually >20 Db.

Transient shielding with higher permeability materials such as 0.8 oz NICKEL is equivalent to 3 oz Copper.

* This work is protected under the author's Patent #4,823,228 and HARRIS Patent Disclosure RA-559, H2722 by Bittner and Reed

NOTICE:

The following is a cursory abbreviated synopsis of this ongoing investigation. The original paper is being revised due to new developments and will be available - by June,1991.

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In evaluating a transient due to Lightning, Switching or EMP **each spectral component (in the frequency domain) starts at zero amplitude at t = Ø** and reaches a maximum as shown in the Figure 1 below - which is somewhat misleading since "Log of time" does not adequately emphasize the much greater delay at lower frequencies. The 2 plots to the right show how much more delay the wave experiences propagating through nickel foil, Ø.6 oz, and 9 oz copper, Ø.Ø126".

Fig 2 provides the solutions for the time delay - the solid line - and the attenuation - the dashed line and emphasizes that at 2ØØ Khz the attenuation has only reduced the wave amplitude to Ø.6 (-4.4 dB) but has delayed the wave **6ØØ nanosec** (pi/4) so that the wave cannot constructively recreate the incident transient due to this time distortion.

\- the equations of Fig 2 are shown more clearly below [ref 1]:

$$V_{cu} = \left(\frac{2\omega}{\mu\sigma}\right)^{1/2} = 0.415\,(f)^{1/2}\ \mathrm{M/S}$$

VELOCITY

ARRIVAL TIME

$$t = 257 \times 10^{-6}\,(f)^{-1/2}\ \mathrm{SECONDS}$$

$$\mathrm{AMPLITUDE} = A_0 e^{-\alpha d} = A_0 e^{-0.0016\,(f)^{1/2}}$$

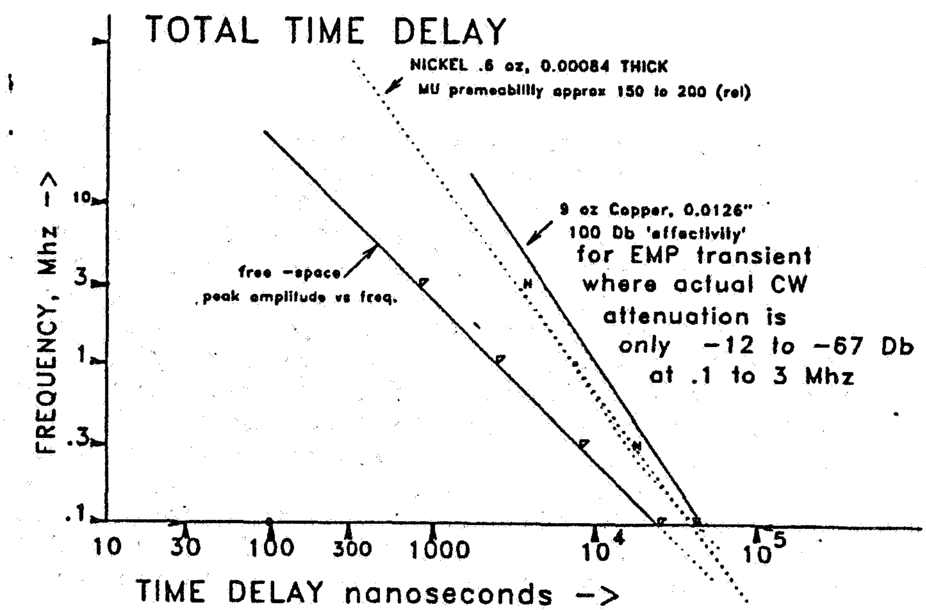


Figure 1

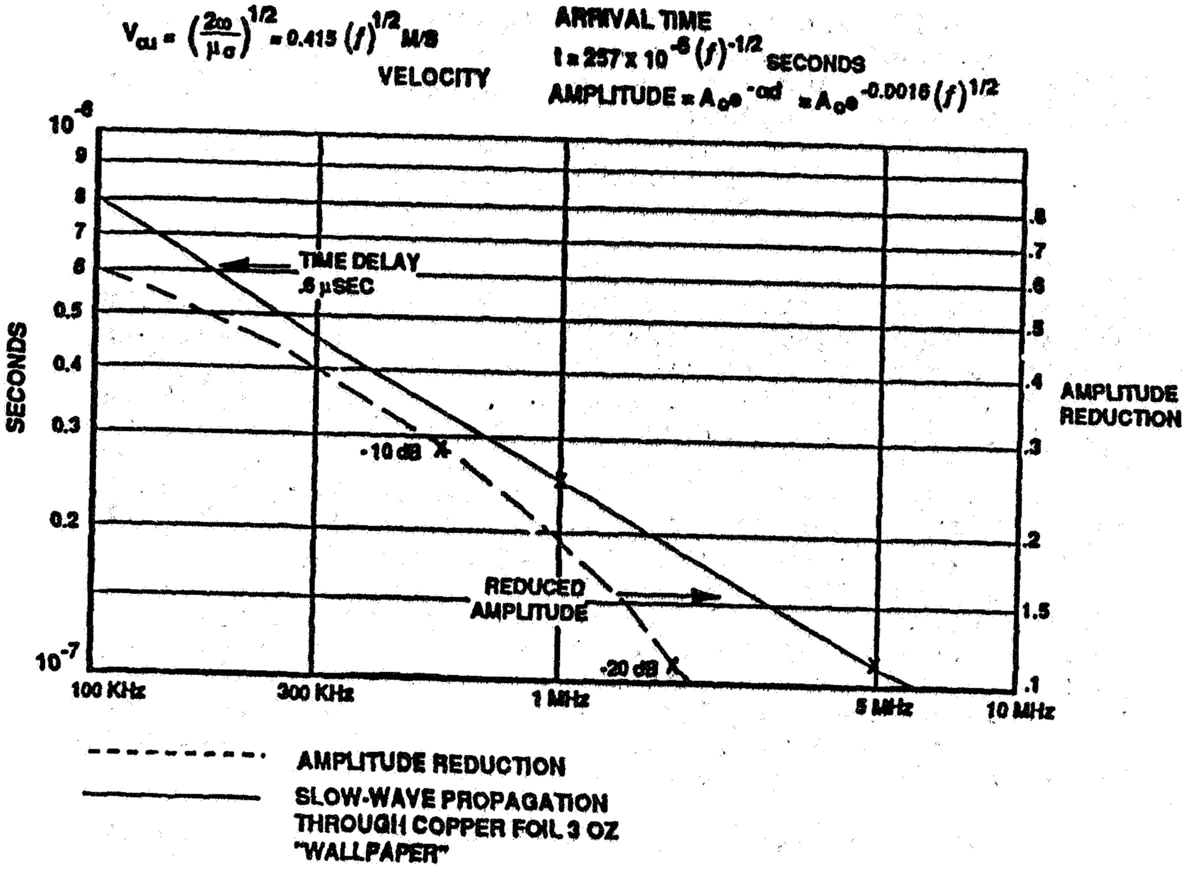
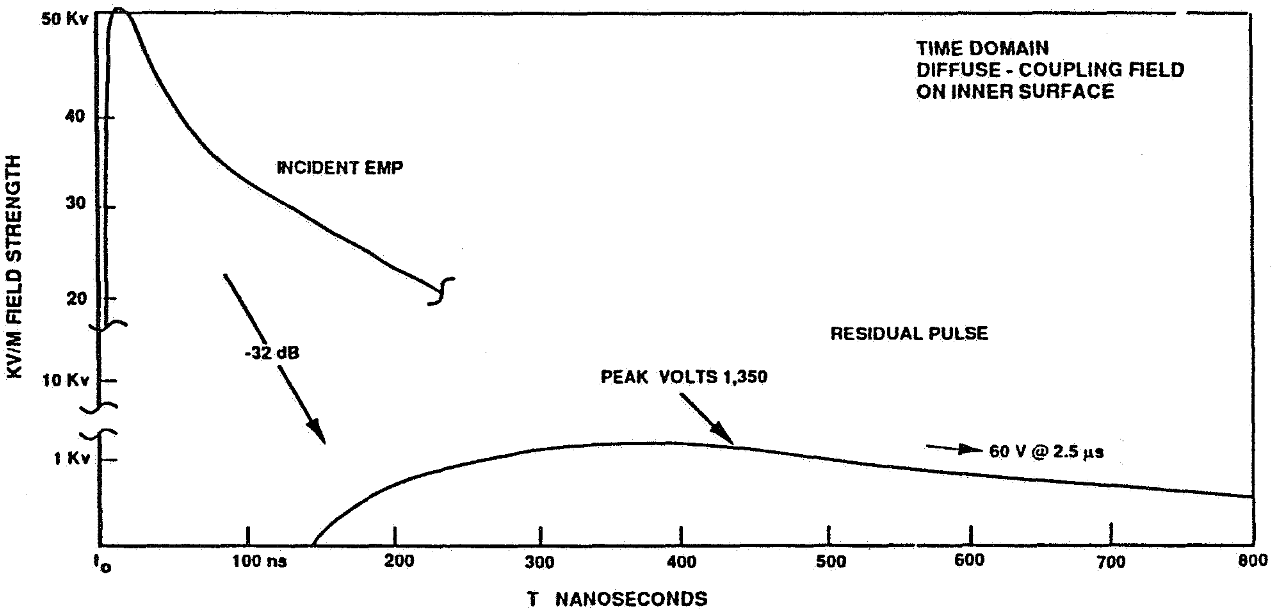


Figure 2

It is often noted that the frequency domain spectrum of lightning and EMP is only 2Ø to 5Ø millivolts per Hz and only the convolution simultaneously creates the fairly large [2] peak amplitudes.

Figure 3 demonstrates how an analysis of transient propagation through a conductive material results in a reduction of the classic HEMP of 52 KV down to less than 1.4 Kv with the peak delayed nearly 4ØØ nanosec. and much of the energy delayed to over Ø.8 microseconds - this time-delayed reconstruction / convolution is a time-consuming computational process and in this figure the amplitude was presumed constant up to 2 Mhz at 3 mv and 2 mv to 1Ø Mhz (- A much more elegant program is needed here! - an invers Fourier ?). This is a true representation of the dispersive delay as it modifies the transient - and cannot be easily reconstructed using just CW test methods since penetration through cracks or ports will combine with the diffuse wave because the time differential amplitudes are lost.



EMP FIELD AT INSIDE SURFACE
USUALLY REDUCED FURTHER BY:
- LOWER INTRINSIC IMPEDANCE AT LOWER FREQUENCIES, $R_s = F(f)^{1/2}$
- STRUCTURES "APERTURES" CANNOT SUSTAIN/INTERCEPT LONG ($\leq$3 MHz) WAVES i.e.; A VERY INEFFICIENT ANTENNA

BASIC AMPLITUDE VS TIME (TIME DOMAIN)
$= A_o$ EXP $-15.1\, d(f)^{1/2}$ SIN ωt

A_o = 0.0037 V/M/Hz to 2 MHz (0.002 TO 10 MHz)

SUM AMPLITUDE COMPONENTS AT (CONVOLUTE)
$T = \Sigma t + 257 \times 10^{-6} (f)^{-1/2}$ SECONDS
t = 25 nsec to 3 MICROSEC

d = THICKNESS (0.0042")
f = FREQUENCY (150 KHz to 10 MHz)
$\omega = 2\pi f$ RADIANS

FIGURE 3

Figure 4 illustrates some examples of dispersive time delay that are of engineering significance **if** shielding from transients is of importance. Note that about 3 oz Nickel (permeability over 100) or 9 oz copper can provide about 100 dB reduction in transients which is mentioned in the proposed MIL-STD-188-125.

Examples are also given for the equivalent '5 mho' sea-water and our newly developed ISIG (TM) thermoplastic which is about six times more conductive than sea-water and is used on the exterior of power and coax cables to absorb the common-mode transients - and in some cases as an overlay for each wire in twisted pairs.

HP has furnished me a fiber-optic circuit that appears to give good data when comparing the phase of the incident CW illumination with the signal inside the shielded enclosure - but it still doesn't provide the total time delay properties of the enclosure and can be very misleading where the CW leakage signal exactly, destructively cancels the diffuse propagated signal.

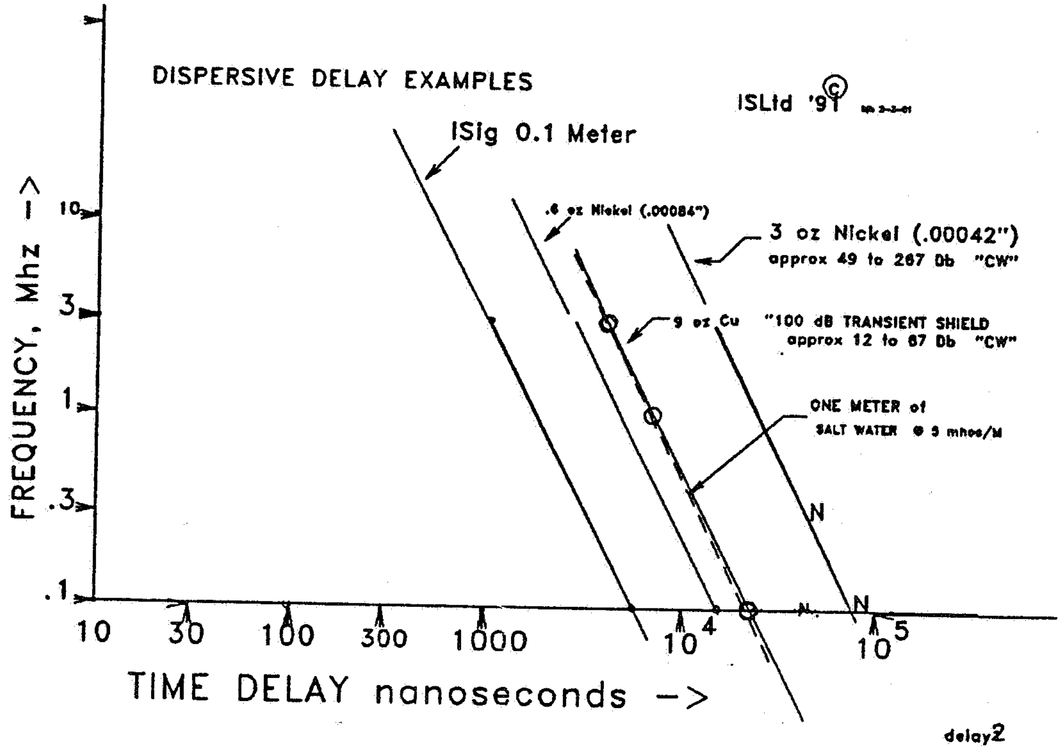


Figure 4

Note should be made that this diffuse delay characteristic is often present on signals intercepted from hi-data rate digital sources - which significantly distorts the waveform intercepted.

references:
[1] E.C.Jordan "Electromagnetic Waves and Radiating Systems" Prentice-Hall, 1950
[2] Frederick M. Tesche, Paul R. Barnes "Transient Response of a Reclosure and Control Unit - - -" IEEE EMC Trans May 1990 p 113
[3] F. M. Tesche
- adv. copy "ON THE USE OF THE HILBERT TRANSFORM FOR PROCESSING MEASURED CW DATA"
-in the HPM issue of EMC Trans. IEEE -